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FINAL REPORT

SPACELAB USER IMPLEMENTATION ASSESSMENT STUDY

Volume III

Resource Requirements Development

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FOREWORD

The Spacelab User Implementation Assessment Study was conducted to assess and minimize the capital investment of the National Aeronautics and Space Administration for the integration and checkout of Spacelab payloads such as Langley's Advanced Technology Laboratory. The study was conducted by the Space Division of Rockwell International Corporation under Contract NAS1-12933 for the Langley Research Center. Mr. F. O. Allamby was the technical study manager for the Langley Research Center. In addition, this study received agency-wide guidance and evaluation from the Steering Group for Payloads Operations Concept Studies, directed by Mr. W. O. Armstrong, to maximize the objectivity and applicability of the study data.

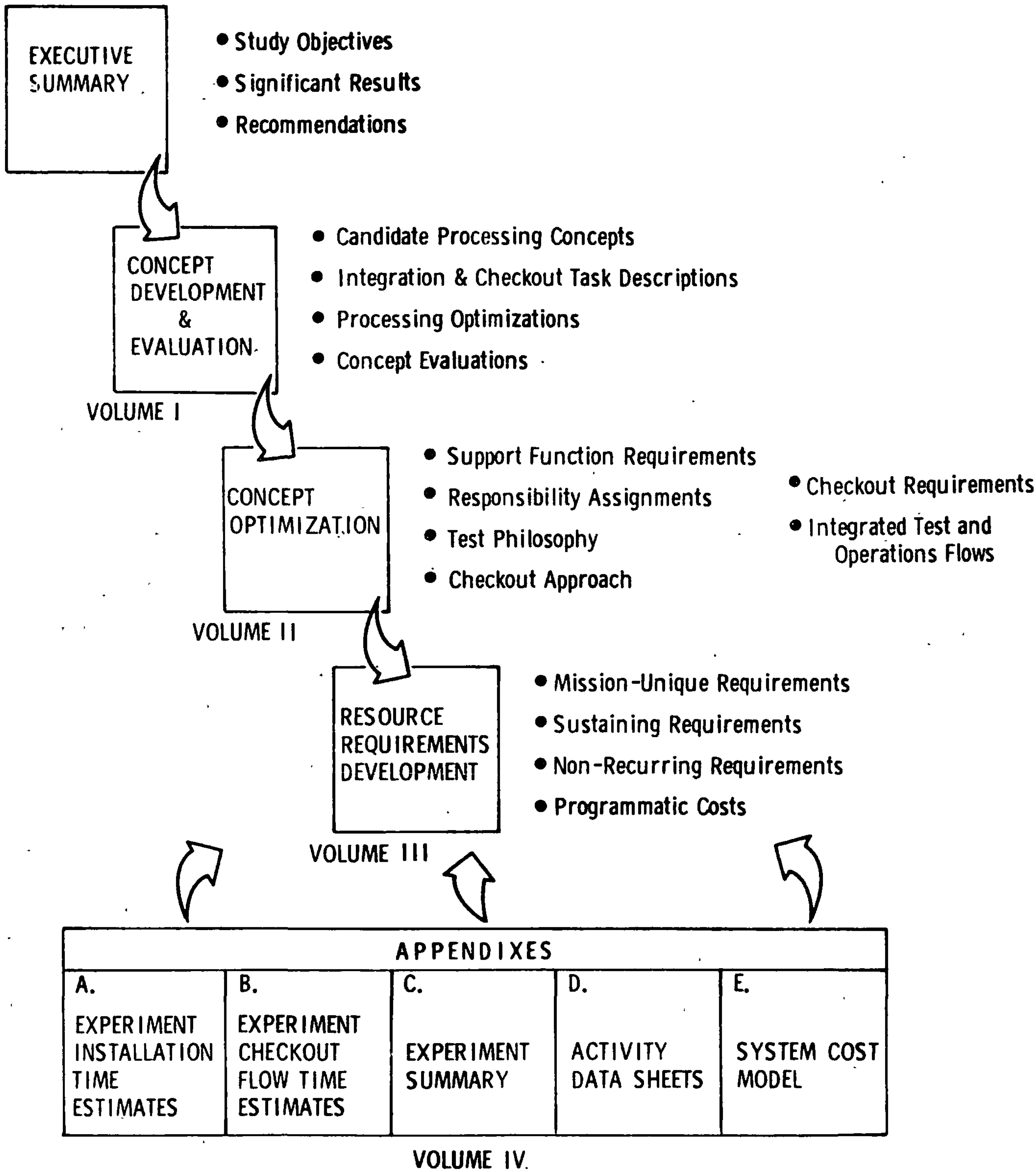
The final report consists of an executive summary and four technical volumes as illustrated in the accompanying figure. A succinct summary of the study is presented in the executive summary. Three of the four technical volumes present the analyses and trades performed during the course of the study. The fourth volume contains five appendixes, which delineate detailed data pertaining to the installation and checkout of Spacelab payloads such as the ATL, and a computer cost model utilized in the compilation of programmatic resource requirements. The contents of the volumes are described below.

EXECUTIVE SUMMARY

- Study overview--objectives, study approach.
- Synopsis of development of candidate processing concepts--complete Spacelab and pallet-only configurations.
- Summary of integration and checkout optimizations--checkout approach, ground operations processing cycle, personnel, ground support equipment and facility requirements.
- Programmatic costing--mission-unique, sustaining, and non-recurring cost estimates for required personnel, material, travel, documentation, ground support equipment, and facilities.
- Concept evaluations--flight-rate sensitivities and concept applicabilities.

VOLUME I. CONCEPT DEVELOPMENT AND EVALUATION

- Complete Spacelab processing concept development.
- Pallet-only processing concept development.



Study Reports

- Results of study optimizations in the areas of checkout requirements, simulator utilization, and configurational changes.
- Flight-rate sensitivities--flight hardware, GSE, facility, and personnel.
- Concept evaluations--integration center/launch site co-location, support module cognizance, WTR implications, general applicability, recommended ATL approach.

VOLUME II. CONCEPT OPTIMIZATIONS

- Supporting functions--development, definitions, and responsibility assignments. Identifies potential software applications.
- Test requirements--checkout approach and requirements, test philosophy, and environmental test requirements.
- Test and operations sequence--development of functional flows, detailed operations, activity data sheets, and integrated flows for both the complete Spacelab and pallet-only processing concepts.

VOLUME III. RESOURCE REQUIREMENTS DEVELOPMENT

- Requirements for mission-unique, sustaining, and non-recurring resources--includes personnel, travel, transportation, material, documentation, GSE, and facilities.
- Programmatic costing--presents cost estimates for all resource requirements.
- Cost-risk analysis--parametric evaluation of deletion of vibra-acoustic, thermal-vacuum and repeat functional tests.

VOLUME IV. APPENDIXES A, B, C, D, AND E

- *Appendix A. Experiment Installation Time Estimates* - Time estimates of the required experiment installation activities including (1) physical installation of experiment hardware in a rack, igloo, or on a pallet; (2) performance of electrical bonding checks; (3) complete mechanical interconnection including fluid and electrical lines; and (4) performance of end-to-end continuity checks between the experiment connector and the interface connector at the experiment module/pallet, support module/experiment module or igloo interfaces.
- *Appendix B. Experiment Checkout Flow Time Estimates* - The general experiment checkout flow plus the time estimates for

each individual experiment in the ATL experiment complement. These time estimates detail the time required for:

- Equipment setup and activation, including controls and display equipment.
- Verification of the operation of mechanical devices of both pallet and rack-mounted sensors and auxiliary equipment.
- Verification of data processing/recording equipment and instrumentation concurrent with checkout of the experiments.

- *Appendix C. Experiment Summary* - A summary of the requirements and equipment utilized for each experiment included in the study. The experiments are listed by discipline.

  - Navigation
  - Earth Observations
  - Physics and Chemistry
  - Microbiology
  - Environmental Effects
  - Components and Systems Testing

  The summary for each experiment includes the objectives or purpose, the description of the equipment utilized, the operation of the equipment, and the physical parameters of mass properties and equipment installation location (pallet, rack, igloo).

- *Appendix D. Activity Data Sheets* - Detailed definitions of the test operations associated with each activity defined in the expanded functional blocks (detailed functional flows). The activity data sheets describe the operations involved and the resources utilized to accomplish the processing cycle. They cover the entire cycle from initial experiment installation through the various integration levels (Experiment, III; Spacelab, II; Orbiter Cargo, I), and the refurbishment of the pallets, racks and/or igloos, following the completion of the mission.

- *Appendix E. System Cost Model* - Description of computer cost model utilized in the study to compile the derived resource requirements into mission-unique, sustaining, and non-recurring cost categories.

Within each volume, the term "concept" is used repeatedly and data are presented with respect to Concepts I through VIII. The concepts referred to pertain to alternate integration and checkout approaches for both the complete Spacelab (support module, experiment module, and pallet) and the pallet-only Spacelab configuration. The following two tables define, in general terms, each of the eight processing concepts that were definitized in this study.

Complete Spacelab Processing Concepts

Concept	Owner			Integration Site	
	Support Module	Experiment Module	Pallet	Experiment Equipment	Spacelab
I	IC	IC	IC	IC	IC
II	LS	IC	IC	IC	LS
III	LS	IC	IC	User	LS
IV	LS	User	User	User	LS
V	User	User	User	User	User

Pallet-Only Processing Concepts

Concept	Owner		Integration Site	
	Pallet	Igloo*	Experiment Equipment	Spacelab
VI	IC	LS	User	LS
VII	IC	LS	IC	LS
VIII	User	LS	User	LS

*Support system igloo and equipment

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ABBREVIATIONS AND ACRONYM LIST

AAFE	Advanced Application Flight Experiments
ADDAS	Automated Digital Data Acquisition System
AEDC	Atomic Energy Development Center
AIM	Apogee Insertion Motor
AM	Airlock Module (Skylab)
ARINC	Aeronautical Radio, Inc.
ARS	Atmospheric Revitalization System
ASO	Airborne Science Office
ATCS	Active Thermal Control Subsystem
ATL	Advanced Technology Laboratory
ATM	Apollo Telescope Mount (Skylab)
CCTV	Closed Circuit Television
CDMS	Command and Data Management System
CER	Cost Estimating Relationship
C.G.	Center of Gravity
CKTS	Circuits
CM	Command Module (Apollo)
CPSE	Common Payload Support Equipment
CRT	Cathode Ray Tube
CSM	Command and Service Module (Apollo)
CV-990	Convair airplane used as test bed in airborne research by NASA-Ames Research Laboratory
DOMSAT	Domestic Satellite (commercial geosynch communications relay)
DPC	Data Processing Center
DWGS	Drawings
ECLSS	Environmental Control and Life Support System
ECS	Environmental Control System
EDS	Experiment Discipline Specialist
EGSE	Electronic Ground Support Equipment
E/I	End Item (hardware)
EM	Experiment Module
EMC	Electromagnetic Compatibility
EMI/RFI	Electromagnetic Interference/Radio Frequency Interference
EPDS	Electrical Power and Distribution System
ERNO	European consortium developing Spacelab
ESRO	European Space Research Organization

FMEA	Failure Mode Effects Analysis
FO	Flight Operations
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
IC	Integration Center (sometimes inferred to be MSFC)
ICD	Interface Control Drawing
I/F	Interface
IMS	Information Management System
INSP	Inspection
IPS	Instrument Pointing System
IU	Instrument Unit (Saturn V Program)
JCL	Job Control Language
JSC	Lyndon B. Johnson Space Center
KSC	John F. Kennedy Space Center
LL	Lower Limit
LS	Launch Site
MCC	Mission Control Center (at JSC)
MCP	Monitor and Control Panel
MDA	Multiple Docking Adapter (Skylab)
MGT	Management
MIL-SPEC	Military Standard Specification
MSFC	Marshall Space Flight Center
MSOB (O&C)	Manned Spacecraft Operations Bldg (now Operations & Checkout)
MSS	Modular Space Station
MP	Mission Planning
NASCOM	NASA Communications Network
NCR	Non-Conformance Report
OBCO	On-Board Checkout
OCC	Operations Control Center (at Spacelab user's site)
O&C	Operations & Checkout Building (formerly MSOB)
OCP	Operational Checkout Procedure
OIT	Orbiter Integrated Test
OMS	Orbital Maneuvering System (Shuttle)
OWS	Orbital Workshop (converted S-IVB structure--Skylab)
OPF	Orbiter Processing Facility
P	Pallet or Pallet Section
PI	Principal Investigator
PS	Payload Shroud (Skylab)
PSS	Payload Specialist Station
QC	Quality Control
R	Rack or Rack Sets
RAU	Remote Acquisition Unit
R/I	Receiving/Inspection
R&QA	Reliability and Quality Assurance

SC 105	Spacecraft 105 (Apollo)
SCM	System Cost Model
SE	Systems Engineering
SIM	Scientific Instrument Model
SL	Spacelab
SM	Support Module
SPECS	Specifications
SSP	Space Shuttle Program
STDN	Space Tracking and Data Network
STS	Space Transportation System
SUIAS	Spacelab User Implementation Assessment Study
TCR	Test and Checkout Requirements
TDRS	Tracking and Data Relay Satellite
T&O	Test and Operations
U	User (inferred to be Langley)
UL	Upper Limit
WBS	Work Breakdown Structure
WTR	Western Test Range

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1.0 INTRODUCTION

1.0 INTRODUCTION

Volume III presents the resource requirements for the integration and checkout of ATL Spacelab payloads in three categories: mission-unique (Section 3.0), sustaining (Section 4.0), and non-recurring (Section 5.0). The requirements are identified by concept and by center. Cost estimates for the resource requirements are also presented (Section 6.0).

The manpower requirements for the mission-unique category have been delineated for the supporting functions (i.e., mission operations analyses, systems engineering, requirements analyses, etc.), and for the test and operations tasks (actual processing of flight hardware). The interrelationship between these two categories determined the manpower optimizations that were used to establish the final program personnel requirements. In addition to personnel headcount requirements, the "support services" factors of material, travel, autocomp (computer) support, documentation, shipping and transportation, and real-time mission support are also included.

The sustaining personnel requirements and associated management structure for each concept for each involved center are presented. Pro-rations of the management organizations at each center are derived to ascertain those efforts/costs that are attributable to integration and checkout activities of the two-flight-per-year ATL program. For example, the management structure at the LS will direct the integration and checkout activities at that site for up to 24 Spacelab payloads per year. Thus, the ATL portion of their effort is only a fraction of the total yearly effort. Although the pro-rations are based on a flight rate of two per year, the organizations are essentially insensitive to flight rate. Therefore, sustaining manpower requirements are on a yearly basis rather than a per-mission basis. Sustaining GSE requirements as well as base support (industrial security, utilities, personnel, etc.) are also defined.

Program estimates for non-recurring requirements are detailed in three parts: non-recurring support, GSE, and facility requirements. A certain start-up operational data pack (i.e., CDMS software, simulation software, payload accommodations documents, etc.) relating to the Spacelab will be provided by the Spacelab manufacturer (ESRO/ERNO), and supplemented by the operations developer, MSFC. But there is also a delta effort that is required by each Spacelab user to adapt the procedures data pack for use within the framework of the unique features of his program. The delta manpower required to factor in the user-unique program requirements is defined. The other non-recurring areas of GSE and facility requirements are also definitized. The GSE requirements for each task of the test and operations (T&O) processing cf the Spacelab are defined for each concept. Within this definition are included those GSE items that will be provided by ESRO with the Spacelab hardware, and those additional items that NASA must provide. The facility estimates are

made for each concept by center. Included with the estimates of area requirements is an analysis of the applicability of existing facilities at three centers (Langley, MSFC and KSC).

The cost estimates for all integration and checkout resource requirements identified in this study are included in the final section of Volume III. These data are grouped in the three cost categories: mission-unique, sustaining, and non-recurring. A cost-risk analysis of the deletions of thermal-vacuum, vibration-acoustic, and repeat functional test sequences is also presented in this section.

2.0 SUMMARY

2.0 SUMMARY

2.0 SUMMARY

Mission-unique manpower requirements were established by estimating the required effort for each integration and checkout task. Depending upon the candidate processing concept, single-center and multiple-center participation in the performance of the tasks was considered. These manpower estimates were converted to personnel requirements at each center for each concept by scheduling and phasing the mission-unique tasks to achieve an optimum-continuing utilization of personnel. This optimization resulted in a three-phase approach to integration and checkout activities: operations analysis and requirements definition, design and fabrication of interfacing hardware, and test and operations. Each phase was intentionally scheduled for a six-month duration. Thus the total integration and checkout cycle for each flight was 18 months. Based upon this optimized staffing approach, the required man-levels at each center for each concept to support a flight rate of two per year are presented in Table 2.0-1.

Table 2.0-1. Mission-Unique Man-Level Requirements (Two Flights Per Year)

SKILL CODE / CONCEPT	I			II & VII			III & VI			IV & VIII		V	
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	LS	U	LS
OPERATIONS ANAL.	8	9	1	8	9	2	15	0	2	15	2	15	1
SYSTEMS ENGINEER	9	18	3	10	15	6	22	3	6	23	6	26	3
DESIGNER	5	(6) 11	(2) 0	5	(6) 10	(2) 1	(4) 8	(6) 6	(2) 1	(12) 12	(2) 1	(12) 13	(2) 0
PROGRAMMER	(2) 0	(3) 3	(1) 0	(2) 0	(3) 3	(1) 0	(3) 3	0	(1) 0	(3) 3	(1) 0	(3) 3	(1) 0
CODER	0	1	0	0	1	0	1	0	0	1	0	1	0
TEST ENGINEER	(2) 0	9	(3) 0	(2) 0	8	(3) 1	9	(3) 0	(3) 1	9	(3) 1	10	(3) 0
TEST TECHNICIAN	0	(5) 9	(8) 0	0	(5) 8	(11) 0	(12) 0	(6) 0	(11) 0	(5) 8	(11) 0	(5) 9	(8) 0
MECHANIC	0	(3) 3	0	0	(3) 3	0	1	(6) 1	0	(6) 2	0	(6) 2	0
TOTALS	(4) 22	(17) 63	(14) 4	(4) 23	(17) 57	(17) 10	(19) 59	(21) 10	(17) 10	(26) 73	(17) 10	(26) 79	(14) 4
		(35) 89			(38) 90			(57) 79		(43) 83		(40) 83	

LEGEND:
(XX) PART TIME
XX FULL TIME

In the area of personnel travel, two categories were identified: test and operations support, and support function liaison. Management, PI, and payload specialist trips were not included in the estimates. The T&O support consists of test engineers that conducted tests at one site, participating in the conduction of tests at a subsequent site. Support function travel includes real-time mission support (10-day duration) and engineering-coordination meetings (2-day duration per trip). Table 2.0-2 summarizes the T&O support travel requirements, and Table 2.0-3 summarizes the supporting functions travel requirements.

Table 2.0-2. Travel Requirements for T&O Support

CONCEPT	I	V	II/VII	IV/VIII	III/VI	
TRIP	IC/LS	U/LS	IC/LS	U/LS	IC/U	U/LS
NUMBER OF PERSONNEL	3		2		2	3
DURATION (DAYS)	9		23		64	24

Table 2.0-3. Support Function Travel Requirements

CONCEPT	USER TO			SUB-TOTAL	IC TO			SUB-TOTAL	LS TO			SUB-TOTAL	CONCEPT TOTAL
	LS	IC	GT		LS	U	GT		IC	U	GT		
I	7	49	20	76	25	21	20	66	11	-	-	11	155
II & VII	18	44	20	82	55	18	20	93	18	-	-	18	193
III & VI	55	9	30	94	-	4	-	4	-	19	-	19	117
IV & VIII	57	-	30	87	-	-	-	-	-	19	-	19	106
V	25	-	30	55	-	-	-	-	-	11	-	11	66

LS: LAUNCH SITE
IC: INTEGRATION CENTER
U: USER
GT: GROUND TRUTH SITE

Each mission is anticipated to require a significant amount of autocomputation time to support the preparation of flight, test and operation software, and support the engineering analysis and design activities. Each WBS task was evaluated (see Section 3.2) to establish the run-time that would be required at each center for a large general-purpose computer such as the IBM 370. These estimates are summarized in Table 2.0-4.

The program documentation requirements were established in a similar fashion by investigating the requirements within each WBS task element, and then analyzing the results to eliminate all possible redundancies. The effort was then directed to the establishment of the minimum quantities of formal documentation that would efficiently transfer the required coordination information between centers. Table 2.0-5 summarizes the total documentation each center is responsible for.

The portions of the manpower requirements for those elements of the program which are necessary to manage and administer the ATL program are summarized in Table 2.0-6. These totals for each center have been developed through the establishment of a center sustaining organization with varying pro-rations applied. The support organizations and the pro-rations applied to establish the ATL portion of the integration and checkout support at each center are discussed in Section 4.1. As in all other manpower charts utilized in this report, all totals are based upon a two-flight-per-year ATL program that reflects an 18-month cycle of integration and checkout activities for each mission.

The final aspects of the total resource requirement for the ATL payload processing concepts are the non-recurring functions that support the integration and checkout in user procedure implementation, GSE development and facility requirements.

There are three distinct categories of support functions development: (1) Spacelab manufacture, (2) Spacelab operations development, and (3) user implementation. The third category is the only aspect chargeable to the integration and checkout activities of the ATL program. Table 2.0-7 illustrates the user mission-unique non-recurring manpower requirements to implement the unique aspects of the ATL program to the generalized Spacelab data package that will be provided by ESRO/ERNO and MSFC.

The program GSE definitions have been divided into two categories: (1) ESRO supplied and (2) NASA supplied. Table 2.0-8 illustrates that there are only minor differences in total GSE requirements for complete Spacelab processing concepts I, II, IV and V. This similarity occurs because only two centers are involved in the T&O activities for these four concepts. However, in Concept III a significant delta GSE requirement occurs, which illustrates the impact of a third center being involved in the flight hardware processing. The same results are obtained from the comparison of the pallet-only processing concepts. Concepts VII and VIII, which involve only two centers in the hardware processing, require significantly fewer GSE end items (133) than Concept VI which involves three centers. Evaluation of the GSE requirements for the processing of the complete Spacelab and pallet-only configurations indicated

Table 2.0-4. Computer Facility Requirements

CONCEPT	I			II & V			III & VI			IV & VIII			V		
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	IC	LS	U	IC	LS
TOTALS (HOURS)	67	39.5	4.5	37	32.9	6.6	101.5	0.4	6.6	101.9	-	6.6	103.5	-	4.5
	111			111.5			108.5			108.5			108		

Table 2.0-5. Summary of Documentation Requirements

	TYPE OF DOCUMENT / CONCEPT	I				II/VII				III/VI				IV/VIII			V		
	CENTER	IC	LS	U	PI	IC	LS	U	PI	IC	LS	U	PI	LS	U	PI	LS	U	PI
OFF LINE	FORMAL	7	1	1	-	8	1	1	-	1	1	7	-	1	8	-	1	7	-
	INFORMAL	2	-	-	-	1	-	-	-	-	-	2	-	-	1	-	-	3	-
	SUPPORT	1	7	5	5	1	8	5	5	6	8	1	5	8	-	5	7	-	4
	TOTALS	10	8	6	5	10	9	6	5	7	9	10	5	9	10	5	8	10	4
		29				30				31				24			22		
IN LINE	FORMAL	16	3	-	-	13	6	-	-	3	6	5	-	6	5	-	3	3	-
	INFORMAL	7	1	6	-	5	3	6	-	-	3	16	-	3	19	-	1	26	-
	SUPPORT	3	9	23	18	7	10	23	18	3	10	10	18	10	7	18	9	3	18
	TOTALS	26	13	29	18	25	19	29	18	6	19	31	18	19	31	18	13	32	18
		86				91				74				68			63		

Table 2.0-6. Pro-Rated Yearly Sustaining Manpower Requirements - Two Flights Per Year (Man-Months)

SKILL CODE / CONCEPT	I			II & VII			III & VI			IV & VIII		V	
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	LS	U	LS
DIRECTORS	8	1	1	8	1	1	8	1	1	8	1	8	1
MANAGERS	60	39	5	60	39	7	72	2	7	72	7	72	5
TECH SPECIALIST	104	-	-	104	-	-	104	-	-	104	-	104	-
ADMINISTRATORS	12	4	2	12	4	4	16	1	4	16	4	16	2
SECRETARIES	44	5	4	44	5	5	56	3	5	56	5	56	4
TOTALS	228	49	12	228	49	17	256	7	17	256	17	256	12
	289			294			280			273		268	

Table 2.0-7. User-Unique Non-Recurring Manpower Requirements

CONCEPT	I			II & VII			III & VI			IV & VIII			V		
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	IC	LS	U	IC	LS
TOTAL (MAN-MONTHS)	35	165	13	35	165	17	253	39	17	276	-	17	380	-	13
	213			217			309			293			393		

Table 2.0-8. ATL Program GSE Requirements Summary

GSE \ CONCEPT	I & V	II & IV	III	VI	VII & VIII
CHECKOUT	56	55	74	57	44
HANDLING	36	43	43	44	43
AUXILIARY	45	49	53	38	29
SERVICING	22	19	25	22	17
TOTAL (END ITEMS)	159	166	195	161	133

that, except for two items, the complete Spacelab GSE can also accommodate the processing of the pallet-only configuration. The two pallet-only unique GSE items were a payload specialist station simulator at the Level III integration site, and systems igloo handling equipment at the Level II integration site.

Facility estimates were made by center for each major integration and checkout activity. These requirements are summarized in Table 2.0-9. These totals contain a 2400 ft^2 allocation at the user's site (in all concepts) for an operations control center (OCC). (See Figure 5.3-10 in Section 5.0.) The unique characteristics of the OCC is the inclusion of a DOMSAT ground terminal. The approach adopted in this study for transfer of flight data to the user's site was a relay link from the TDRS ground terminal at White Sands, New Mexico, via a domestic geosynchronous communications satellite (DOMSAT) to the user's site. Evaluation of the potential applicability of existing or planned buildings at Langley, MSFC and KSC indicated that, with modifications, existing buildings at all three centers would meet or exceed the facility requirements identified in this study.

The final section of Volume III (6.0) summarizes the programmatic costs for the eight Spacelab processing concepts. The costs are presented in three categories: mission-unique, sustaining, and non-recurring. Mission-unique costs pertain to those items that are directly attributable to the ground operations of one particular flight (Table 2.0-10). Sustaining costs (Table 2.0-11) are primarily associated with administrative and maintenance activities, which are relatively independent of flight rate and thus are presented on a yearly basis. Non-recurring costs (Table 2.0-12) include the initial effort to adapt the Spacelab documentation and procedures to a specific user, and the capital investment for GSE and facilities to conduct Levels III, II, and I integration.

A cost-risk analysis of thermal-vacuum, vibration-acoustic, and repeat functional testing indicated that with reasonable probabilities of failure on multi-experiment Spacelab payloads such as the ATL, it would be more cost-effective to delete these tests from the sequence of test and operations performed on the integrated payload. Thermal-vacuum and vibration-acoustic testing of individual experiment equipments is assumed. The checkout approach adopted in this study reflects a progressive buildup in assembly levels. Tests at one assembly level are not repeated at a higher assembly level; only the interfaces/interconnection that result from the progressive assembly of the payload/Spacelab/Orbiter are verified.

Table 2.0-9. Summary of Facility Requirements

CONCEPT	I			II & VII			III & VI			IV & VIII			V		
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	IC	LS	U	IC	LS
TOTAL (FT^2) SITE	10,000	30,200	13,600	10,100	29,700	23,028	28,900	12,800	23,028	34,400	-	23,028	34,900	-	13,600
CONCEPT	53,800			62,828			64,728			57,428			48,500		

Table 2.0-10. Mission-Unique Costs Per Mission
(Thousands of Dollars)

COST ITEM / CONCEPT	I			II & VII			III & VI			IV & VIII		V	
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	LS	U	LS
MATERIAL	--	69	--	--	69	--	37	32	--	69	--	69	--
TRAVEL	30	28	2	32	32	3	45	4	5	43	4	37	2
AUTO COMP	16	10	1	16	9	2	25	--	2	25	2	25	1
DOCUMENTATION	2	3	--	2	3	1.5	3	1.5	1.5	3	2	3	1
SHIPPING/TRANSPORT	16	24	--	16	24	--	44	12	--	32	--	32	--
FACILITIES	40	--	--	40	--	--	40	--	--	40	--	40	--
PERSONNEL	373	1005	148	392	916	258	1019	264	258	1230	258	1321	148
TOTALS	477	1139	151	498	1053	264.5	1213	313.5	266.5	1442	266	1527	152
	1767			1815.5			1793			1708		1679	

Table 2.0-11. Yearly Sustaining Costs (Thousands of Dollars)

COST ITEM / CONCEPT	I			II/VII			III/VI			IV/VIII		V	
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	LS	U	LS
GSE MAINTENANCE	--	21	2	--	18	4	18	4	4	18	4	21	2
FACILITY MAINT.	--	12	1	--	12	2	12	3	2	12	2	12	1
INSTITUTIONAL BASE & OTHER ADMIN.	22	38	6	23	35	10	46	10	10	54	10	57	6
PERSONNEL	494	140	26	494	140	35	550	14	36	550	36	550	36
TOTALS	516	211	35	517	205	52	626	31	52	634	52	640	35
	762			774			709			686		675	

Table 2.0-12. Composite Non-Recurring Costs (Millions of Dollars)

COST ITEM / CONCEPT	I			II/VII			III/VI			IV/VIII		V	
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	LS	U	LS
FACILITIES	0.5	3.5	0.5	0.5	3.5	0.5	2.4	3.5	0.5	2.4	0.5	2.4	0.5
GSE	--	8.9	4.9	--	6.4	8.6	6.1	2.7	8.6	6.4	8.6	8.9	4.9
SPARES	--	2.7	0.8	--	2.4	2.2	2.4	0.1	2.2	2.4	2.2	2.7	0.8
PERSONNEL	*	0.4	*	*	0.4	*	0.6	0.1	*	0.6	*	0.9	*
TOTALS	0.5	15.5	6.2	0.5	12.7	11.3	11.5	6.4	11.3	11.8	11.3	14.9	6.2
	22.2			24.5			29.2			23.1		21.1	

*LESS THAN $100K

3.0 MISSION-UNIQUE PERSONNEL REQUIREMENTS

3.0 MISSION-UNIQUE REQUIREMENTS

This section establishes the mission-unique personnel and support service resource requirements for the eight (five complete Spacelab and three pallet-only) processing concepts evaluated during the SUIAS study.

Since one of the major recurring cost elements in any operational program such as ATL Spacelab is the cost of the salaries of the prsonnel involved in the program, major attention was given to the trades and analyses that establish personnel requirements for the two major mission-unique activities: support functions, and test and operations. This section presents the analyses that led to the task sequencing of T&O functions and the support functions. The interrelationship between the time required to perform the T&O activities and the time required for the support function activities was examined and optimized. The analyses were conducted in order to determine whether there was an efficient balance between these activities such that the transition of personnel assignments from one mission to another could be accomplished in a manner that minimized inefficiencies and slack periods. The smooth transfer of personnel performing related tasks from one flight to another was the key desired end result.

Manpower estimates for each support function task are presented. Schedules of support function manpower spreads by month, skill code, center, and concept are provided. The use of a phased manpower approach and task sequence, together with the computer techniques for manpower loading and smoothing are discussed. Compilations of the mission-unique support function effort for each center for each concept are presented as a function of man-months and man-level.

An evaluation of the potential differences in the required support functions for the integration and checkout of the two Spacelab configurations (complete Spacelab and pallet-only) is presented. The differences between corresponding processing concepts (II and VII, III and VI, and IV and VIII) are negligible.

Estimates for each task of the test and operations activities were developed on the basis of the maximum number of personnel that could be effectively used for a given task. Minimization of the ground operations involvement time of the Spacelab hardware was the primary objective. This approach resulted in significant variations in the required number of test personnel. However, by utilizing part-time technician help, combining the requirements for test engineers for support function and test and operations activities, and using a weighted average approach for staffing, slack or non-productive periods for test and operations personnel were reduced to a tolerable level. Test and operations personnel requirements for the processing of the complete Spacelab and pallet-only configurations were identified for corresponding complete Spacelab and pallet-only concepts (II and VII, III and VI, and IV and VIII).

Composite (support function and test and operations) mission-unique man-month and man-level requirements are presented by skill code and WBS group for each center for each concept. The required level of effort to accomplish the mission-unique tasks varied from 610 to 654 man-months across the candidate processing concepts.

In addition to the personnel requirements for mission-unique functions, there are associated support services that are vital in the development of overall costs for a program. Material, personnel travel, computer facility operations, documentation, and flight hardware shipping and transportation are included in the establishment of the total mission-unique resource requirements.

Materials estimates are defined for such items as the fabrication of mockups, cables, mounts and enclosures. They are the same for each concept--only the cognizant responsible center varies.

Personnel travel estimates are given for support function liaison and for off-site T&O support. No estimates were made for management, PI, or payload specialist trips.

The computer facility requirements were defined by WBS task. The estimates reflect the run-time on the computer.

Documentation requirements were established in order to define the minimum formal documentation required for the exchange of interface and support requirements between centers. Intra-center (informal) and support documentation are also identified. The documentation estimates and descriptions of each of the documents are provided.

Shipping and transportation estimates for the Spacelab hardware elements and the experiment equipment were made for each center by concept. Pre-flight shipments were assessed to the "sender"; post-flight shipment was assessed to the "receiver." In no case was the LS assessed for shipments.

The manpower required to accomplish the support services described herein was included in the support function and test and operations task estimates. Only the "other cost dollar" resources were included in the support services estimates.

3.1 MISSION UNIQUE PERSONNEL REQUIREMENTS

ESTIMATING AND OPTIMIZATION TECHNIQUES

Of all the cost elements in a continuing program, the salaries of the personnel involved is one of the largest. Thus, the concept optimization studies (described in Volume II) emphasized processing techniques that would minimize the total man-months of effort required. But minimizing man-months of effort is an incomplete solution; scheduling and phasing tasks must be such that personnel assigned to the program are effectively employed. The approach used was to vary the manpower assigned to specific tasks to achieve a combination of dedicated/full-time personnel and part-time specialist support that could be shared with other Spacelab payload processing activities.

Task Sequencing

The initial scheduling of tasks was accomplished on the basis of achieving the minimum time duration from initiation of analyses through post-flight refurbishment. The task logic (series-parallel relationships) is illustrated in Figure 3.1-1. The tasks that are considered to be the pacing items are indicated in the emphasized circles. The time duration achieved was about 15 months. The last 6 of these months were fixed by the physical constraints of the test and operations activities. In Volume II, it was reported that the nominal minimum time for test and operations for all the processing concepts was 6 months. Additional personnel could not appreciably decrease the processing time. Only so many people can work on a given set of equipment at any one time.

Although a minimum time duration was achieved for the complete integration cycle, the supporting function efforts were on a 9-month cycle, while the test and operations activities were on a 6-month cycle. This resulted in a 3-month slack period for the test and operations personnel and also achieved two flights per year only every third year (Figure 3.1-2).

It would be impractical to temporarily reassign a staff of personnel every six months for a three-month duration. Lengthening the duration of the test and operations activities to nine months is also unacceptable. One of the prime drivers in the cost of the Spacelab program is the number of Spacelabs required to support multiple flights per year. It is imperative that Spacelab flight hardware be cycled and recycled as quickly as possible to reduce the inventory to a minimum. Therefore the time duration of the test and operations activities was fixed at 6 months. Modifications to the scheduling and staffing of the supporting functions were evaluated to define a technique that would result in steady-state gainful assignments for the staff.

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Figure 3.1-1. Task Logic Flow Diagram

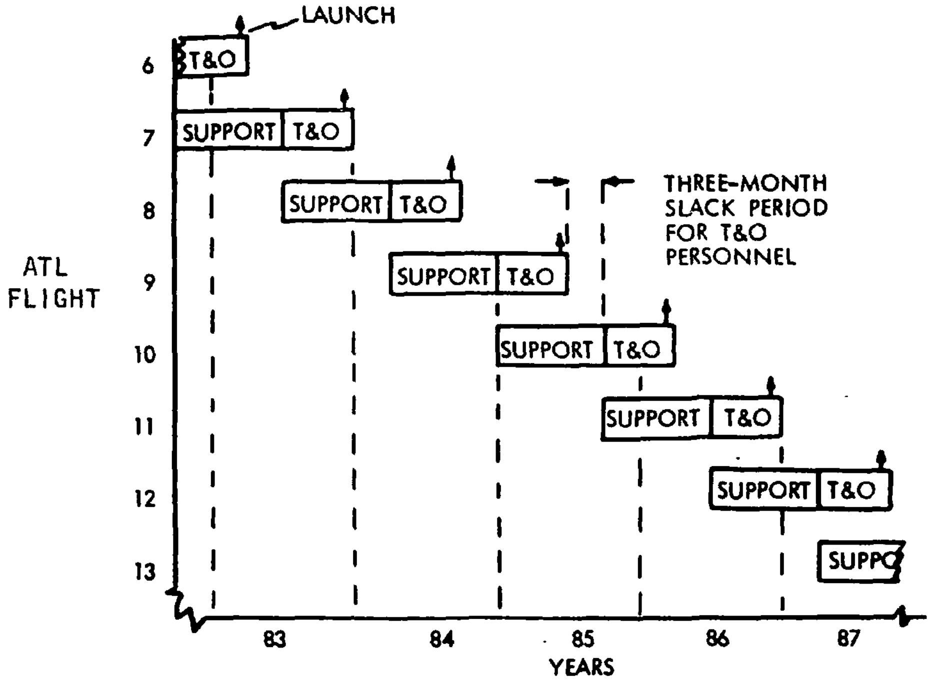


Figure 3.1-2. Minimum Single Mission Integration Schedule

Analysis of the specific support function tasks indicated that there were two discrete phases in the effort: (1) operations analysis and requirements definition, and (2) design and fabrication. Also, in order to estimate realistic personnel requirements (in addition to man-months of effort) it was mandatory to use skill codes (operations analyst, systems engineer, programmer, coder, test engineer, etc.) rather than just skill levels (engineer, technician, administrator, etc.). This further breakdown of personnel and task phasing indicated that with only a nine-month period for support function activities, there also would be slack periods for the various skill codes for a continuing program such as the ATL. But, if each of the supporting function phases were intentionally scheduled for the same duration as the test and operations activities, it was feasible to achieve a constant requirement for the various skill codes. Therefore, the supporting function tasks were intentionally scheduled and staffed to achieve a six-month duration for each of the two phases. The composite steady-state integration process for a continuing program such as the ATL is shown in Figure 3.1-3. The resulting integration and checkout cycle for each mission is 18 months with, at any given time, three missions in process. Within any given calendar year, each of the three phases of integration and checkout is accomplished twice, although four different missions are involved. For example, in Figure 3.1-3, during 1984 the test and operations phases for the 9th and 10th ATL flights, the design and fabrication for the 10th and 11 flights, and the analyses and requirements for the 11th and 12th flights all occur. Also, each phase of the integration and checkout cycle is occurring concurrently.

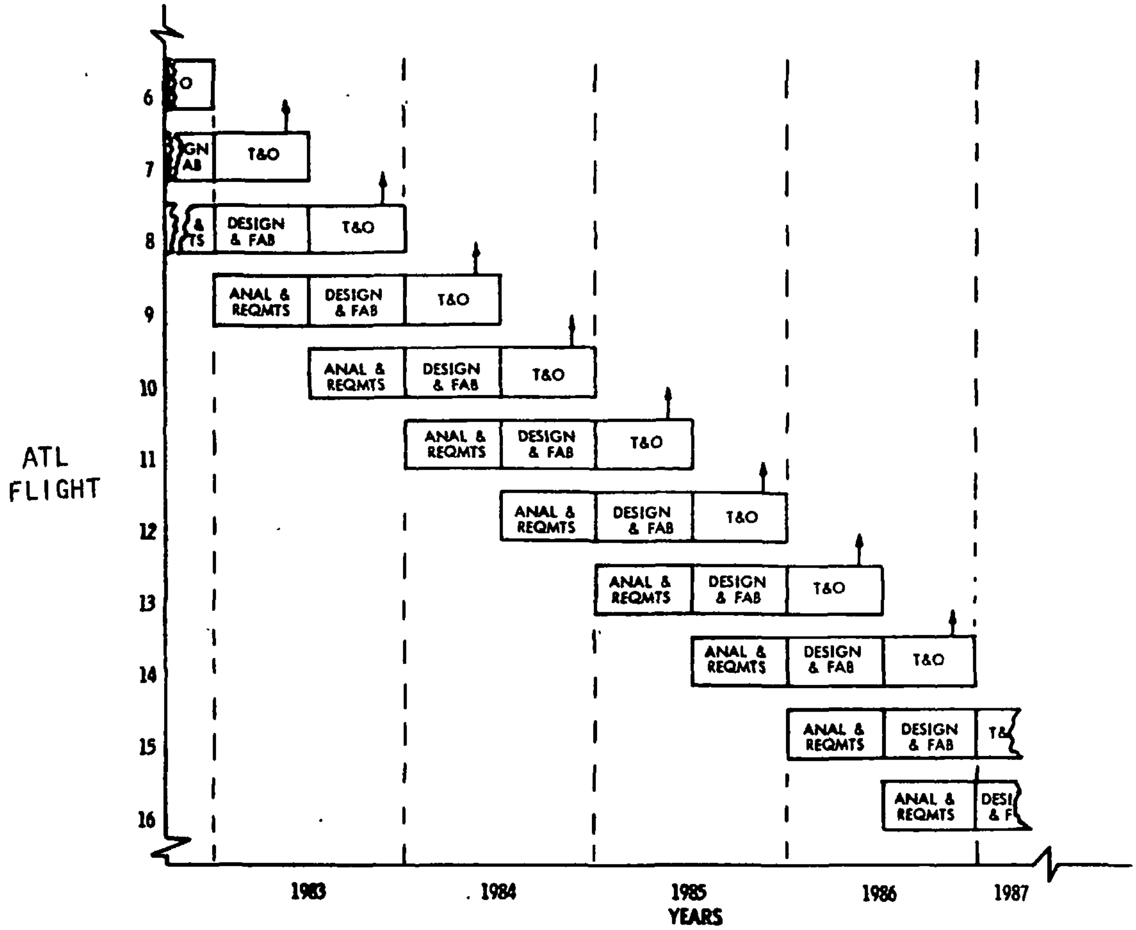


Figure 3.1-3. Steady-State Phased Mission Development

Manpower Estimating

Each task defined in the WBS (presented in Volume I) was analyzed to determine if mission-unique supporting function effort was involved. Based upon previous programs, skill code requirements and man-months of effort were identified to accomplish each basic task. The responsibility criteria developed in Volume II were used to determine the primary and support centers for each task. Regardless of concept, the estimates for a specific task to be performed by the responsible or lead centers were the same. Where applicable, the effort was shared by multiple centers and a delta effort was estimated for support, coordination, review, approval, etc., at other involved centers. Matrices, as depicted in the example shown in Figure 3.1-4, were developed for each concept to identify the primary and support centers and the required skill codes. (The actual matrices are shown in Tables 3.1-2 through 3.1-6, inclusive.)

Based upon the three-phase integration and checkout approach, skill code estimates were made for each task to accomplish that task in accordance with the logic of Figure 3.1-1. As the schedule for initiation, peak effort, and completion of work is dependent upon the nature of the task, several different manpower spreading curves were utilized. With the aid of the System Cost Model (SCM) computer program (Appendix E), the tabulation of manpower requirements by skill code and center was accomplished.

CONCEPT III

CONCEPT II

CONCEPT I

WBS ITEM		BASIC MAN-MONTHS	CENTER: USER	CENTER: INTEGR	CENTER: LAUNCH SITE	SKILL CODES: OPS ANALYST	SYSTEM ENGINEER	DESIGNER	PROGRAMMER	CODER	TEST ENGR	MECHANIC
30-10-10	EXPMT REQMTS	4	P			✓						
30-10-20	ORBIT/TRAJ.	4		P		✓						
30-10-30	MISSION TL	4		P		✓						
30-20-10	OPS PLAN	5		P	S	✓						
30-20-20	RESOURCE ALLOCA.	5		P	S	✓						
30-20-30	CREW TL	5		P		✓						
30-20-40	CREW SKILL	2		P		✓						
30-30-10	MISSION PLAN	4	S	P	S	✓						
40-10	MISSION CONTROL	1		P	S	✓						
40-20-10	OPS MONITOR RM	4	P	S	S		✓					
40-20-20	DATA XMISSION	1	P	S								✓
40-30-10	GROUND TRUTH	72	P	S		✓	✓					
40-30-20	SL SYS SUPPORT	8		P			✓					
50-10-10-10	PERFORM EVAL	27	S	P	S		✓					
50-30-10-10	ORB SOFTWARE	4	S	S	P				✓			
50-30-10-20	SL/EXP SOFTWARE	8	S	P					✓			
50-30-20-10	FLT OPS SOFTWARE	14		P					✓	✓		
50-30-20-20	C/O SOFTWARE	12		P					✓	✓		
60-10-10	CABLES/WIRE	16		P				✓				✓
60-10-20	STRUCTURES	23		P				✓				✓
60-10-30	ENCLOSURE	3		P				✓				✓
60-20-10	TEST PLANS	30	S	P							✓	
60-20-20	TEST RESULTS	2		P							✓	
66-40-10	SAFETY	1	S	S	P		✓					
70-10-30	STE	4		P				✓			✓	✓

LEGEND:

P Primary
S Support

Figure 3.1-4. Task Estimate Matrices
(Example)

Manpower Optimization

The SCM tabulation presented the skill code personnel requirements for the supporting function activities for a single mission over an 18-month duration. Although most of the skill codes are required during all three integration and checkout phases, the level of personnel required fluctuates significantly if only a single mission is considered. To determine the total personnel requirements at any given time, the concept of three missions in process and all three integration and checkout phases occurring simultaneously must be considered. That is, a three-by-foldover of the SCM tabulation is required.

Figure 3.1-5 illustrates the method used in the derivation of the composite personnel requirement for each skill code. The example shown is for the operations analyst skill code at the user site for Concept V. The curve in the lower left indicates the personnel requirements for an operations analyst to perform various tasks during the test and operations phase of a particular mission. Simultaneously, during the same 6-month interval, the personnel requirements for an operations analyst to perform other tasks on a second mission that is in the design and fabrication phase, and a third mission that is in the operations analysis and requirements phase, are shown in the middle and upper-left graphs, respectively. The composite steady-state requirement for an operations analyst at the user's site is shown by the curve on the right to be 15 people.

A similar foldover of personnel requirements was performed for each significant skill code for each center for each concept. In some cases, minor adjustments were required in the staffing, scheduling, and/or spreading estimates. The total man-months per task were held constant.

Development of test procedures and preparation of test reports were arbitrarily included as part of the supporting functions and, thus, these tasks are also included in Table 3.1-1. A skill code tabulation of the manpower requirements for the supporting functions for the five complete Spacelab processing concepts is presented in Tables 3.1-2 through 3.1-6. The spreading options are summarized in Figure 3.1-6. A detailed explanation of the spreading functions is included in the SCM discussion contained in Appendix E. Table 3.1-7 summarizes the skill-code manpower requirements to accomplish the supporting functions for each mission.

Personnel Requirements

The SCM program was used to obtain the skill-code manpower requirements for each month of the 18-month integration and checkout cycle. The composite supporting function personnel requirements to process three ATL missions simultaneously were determined by the three-by-foldover of a single mission SCM printout as illustrated in Figure 3.1-5.

In some cases, the nature of the task did not warrant spreading of manpower to achieve a constant level. For example, design work, cable assembly, interface hardware fabrication, and software development are more efficiently accomplished with a concentrated effort. Therefore, part-time personnel requirements were established for such skill codes as designers, programmers and mechanics. In those concepts where user part-time personnel are required, the required skill codes could be shared between the Integration and Checkout organizations and the Experiment Development organization (see Section 4.1). Part-time personnel at the IC and LS could support the processing of Spacelab flights other than just the two yearly ATL flights baselined in this study.

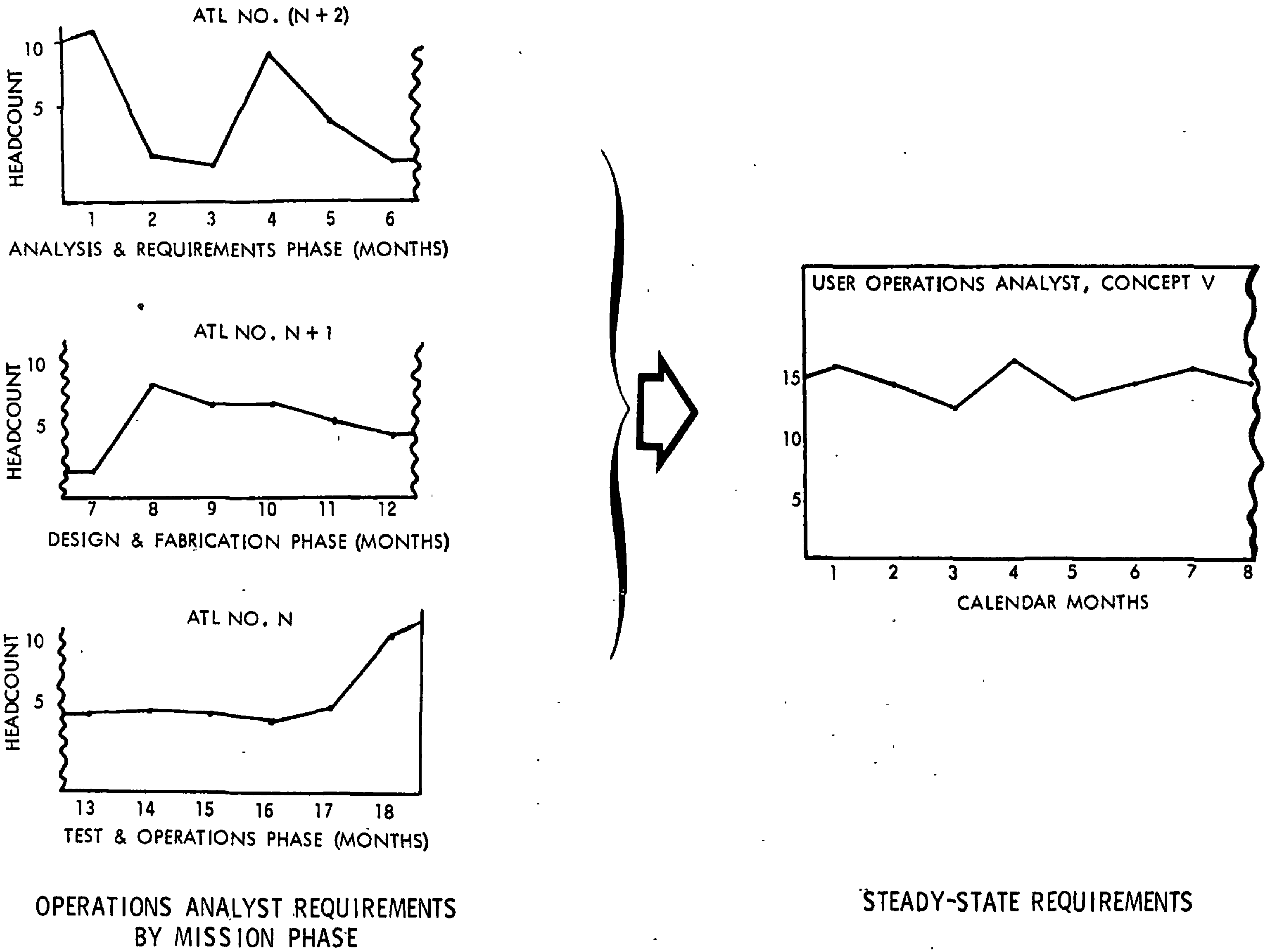


Figure 3.1-5. Composite Skill Code Requirement Example

Table 3.1-1. Support Function Schedule of Tasks

WBS TASKS	
30-10-10	EXPERIMENT REQUIREMENTS
30-10-20	ORBIT & TRAJECTORY ANALYSIS
30-20-10	OPERATIONS PLANNING
30-20-40	CREW SKILLS
50-10-10-10	PERFORMANCE EVALUATION
30-10-30	MISSION TIMELINES
30-20-20	RESOURCE ALLOCATION
50-10-10-30	EMI ANALYSIS
50-10-20	FLIGHT & GROUND REQUIREMENTS
30-20-30	CREW TASK TIMELINES
40-30-10	GROUND TARGET/TRUTH SITE
50-50-20	SAFETY ANALYSIS
30-30-30	GROUND SUPPORT PLANS
30-50-10	TRAINING PLANS AND PROCEDURES
50-10-30-10	TESTS, PARAMETERS AND LIMITS
50-40-20	RELIABILITY ANALYSIS
50-10-30-20	CONFIDENCE, COST/RISK ANALYSIS
50-20-40	COSTS AND COMMONALITY ANALYSIS
50-30-10-20	SPACELAB AND EXPERIMENT SOFTWARE REQUIREMENTS
50-20-10-20	EQUIPMENT SPECIFICATION
50-20-10-30	CPSE COORDINATION
50-20-30-10	ICD'S
50-30-10-10	ORBITER SOFTWARE REQUIREMENTS
50-20-10-10	SYSTEM OPERATING INSTRUCTIONS
50-20-20-10	LAYOUT AND INSTALLATION DESIGN
50-20-20-20	INTERFACE HARDWARE DESIGN
50-30-20-10	FLIGHT OPERATIONS SOFTWARE DEVELOPMENT
50-10-10-20	EXPENDABLES AND LOADS
50-20-20-30	TURNAROUND AND REFURBISHMENT PLAN
50-20-20-20	CHECKOUT & PERFORMANCE MONITOR SOFTWARE DEV
50-50-30	SAFETY REVIEW
50-80	CONFIGURATION CONTROL
60-10-10	CABLE AND WIRE FABRICATION
60-10-20	STRUCTURES FABRICATION
50-10-40	GSE & FACILITY REQUIREMENTS
30-30-10	MISSION PLANS
50-60	MOCKUPS
60-10-30	PROTECTIVE ENCLOSURES
30-10-30	SPECIAL TEST EQUIPMENT
30-30-20	MISSION OPERATING INSTRUCTIONS
60-20-10	INSTALLATION AND CHECKOUT PLANS
30-50-20	TRAINING ACTIVITY
63-20-10	SPACELAB INTEGRATED TEST PLANS
66-20-10	CARGO INTEGRATION TEST PLANS
50-40-30	QUALITY CONTROL INSPECTION
60-50	INSTALLATION AND CHECKOUT TEST & OPERATIONS
60-20-20	INSTALLATION AND CHECKOUT TEST REPORTS
63-50	SPACELAB INTEGRATION TEST AND CHECKOUT
63-20-20	SPACELAB INTEGRATION TEST REPORT
66-50	ORBITER CARGO INTEGRATION TEST AND CHECKOUT
66-20-20	ORBITER CARGO INTEGRATION TEST REPORTS
66-40	ORBITER SAFETY REVIEW
40-10	MISSION CONTROL
40-20-10	OPERATIONS MONITOR ROOM
40-20-20	DATA TRANSMISSION
40-30-20	SPACELAB SYSTEMS SUPPORT
30-40-10	EXPERIMENT FLIGHT DATA ANALYSIS
30-40-20	MISSION REPORT
50-30-20-40	REPAIR AND REFURBISHMENT REQUIREMENTS

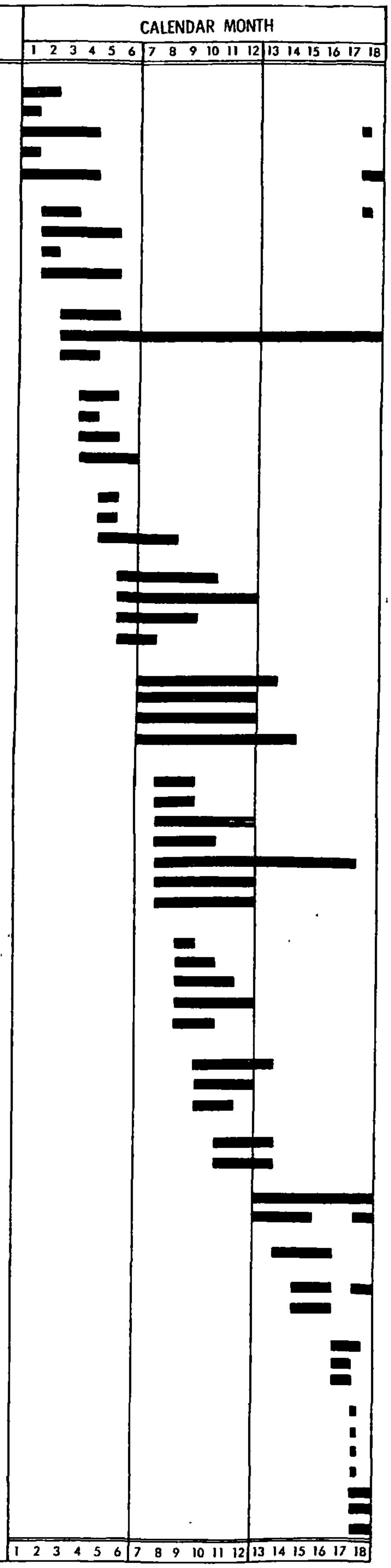


Table 3.1-2. Concept I Supporting Function Task Estimates

WBS NO.	TASK TITLE	CENTER	SKILL CODE	MAN MONTHS	SPREAD OPTION			
					BEGIN	PEAK	END	TYPE
30 10.11.	EXPERIMENT REQUIREMENT	USER	OPS ANAL	8	1	0	2	4
30.10.21.	ORBIT TRAJECTORY ANALYSIS	IC	OPS ANAL	2	1	0	1	4
30.10.31.	MISSION TIMELINES	IC	OPS ANAL	1	18	0	18	4
30.10.32.	MISSION TIMELINES	IC	OPS ANAL	4	2	0	3	4
30.20.11.	OPERATIONS PLANNING	IC	OPS ANAL	3	1	1	4	3
30.20.12.	OPERATIONS PLANNING	LS	OPS ANAL	1	2	0	3	4
30.20.13.	OPERATIONS PLANNING	IC	OPS ANAL	1	18	0	18	4
30.20.21.	RESOURCE ALLOCATION	IC	OPS ANAL	1	18	0	18	4
30.20.22.	RESOURCE ALLOCATION	LS	OPS ANAL	1	2	0	3	4
30.20.23.	RESOURCE ALLOCATION	IC	OPS ANAL	3	2	1	5	3
30.20.31.	CREW TASK TIMELINES	IC	OPS ANAL	5	3	0	5	4
30.20.41.	CREW SKILLS	IC	OPS ANAL	2	1	0	1	4
30.30.11.	MISSION PLANS	USER	OPS ANAL	2	9	0	10	4
30.30.12.	MISSION PLANS	IC	OPS ANAL	4	8	0	10	4
30.30.13.	MISSION PLANS	LS	OPS ANAL	1	9	0	9	4
30.30.21.	OPERATING INSTRUCTIONS	USER	OPS ANAL	4	10	1	13	3
30.30.22.	OPERATING INSTRUCTIONS	IC	OPS ANAL	8	10	1	13	3
30.30.23.	OPERATING INSTRUCTIONS	LS	OPS ANAL	1	11	0	11	4
30.30.31.	GROUND SUPPORT PLANS	USER	OPS ANAL	4	4	0	5	4
30.30.32.	GROUND SUPPORT PLANS	IC	OPS ANAL	2	4	0	5	4
30.30.33.	GROUND SUPPORT PLANS	LS	OPS ANAL	1	5	0	5	4
30.40.11.	EXPERIMENT FLIGHT DATA ANALYSIS	USER	SYS ENGR	2	18	0	18	4
30.40.21.	REPORT PREPARATION	USER	SYS ENGR	1	18	0	18	4
30.40.22.	REPORT PREPARATION	IC	SYS ENGR	1	18	0	18	4
30.40.23.	REPORT PREPARATION	LS	SYS ENGR	1	18	0	18	4
30.50.11.	TRAINING PLANS AND PROCEDURES	USER	OPS ANAL	2	4	0	4	4
30.50.12.	TRAINING PLANS AND PROCEDURES	IC	OPS ANAL	3	4	0	4	4
30.50.13.	TRAINING PLANS AND PROCEDURES	LS	OPS ANAL	1	4	0	4	4
30.50.31.	TRAINING ACTIVITY	USER	SYS ENGR	2	10	0	11	4
30.50.32.	TRAINING ACTIVITY	IC	SYS ENGR	6	10	0	11	4
40.10.11.	MISSION CONTROL	USER	OPS ANAL	1	17	0	17	4
40.10.12.	MISSION CONTROL	IC	OPS ANAL	2	17	0	17	4
40.10.13.	MISSION CONTROL	LS	OPS ANAL	1	17	0	17	4
40.20.11.	OPERATIONS MONITOR RM	USER	OPS ANAL	3	17	0	17	4
40.20.12.	OPERATIONS MONITOR RM	IC	OPS ANAL	3	17	0	17	4
40.20.13.	OPERATIONS MONITOR RM	LS	OPS ANAL	1	17	0	17	4
40.20.21.	DATA TRANSMISSION	USER	MECHANIC	1	17	0	17	4
40.20.22.	DATA TRANSMISSION	IC	MECHANIC	1	17	0	17	4
40.30.11	GROUND TRUTH SITE	USER	OPS ANAL	24	3	13	18	3
40.30.12.	GROUND TRUTH SITE	IC	OPS ANAL	12	3	13	18	3
40.30.13.	GROUND TRUTH SITE	USER	SYS ENGR	24	3	13	18	3
40.30.14.	GROUND TRUTH SITE	IC	SYS ENGR	12	3	13	18	3
40.30.31.	SPACELAB SUBSYSTEMS SUPPORT	IC	SYS ENGR	8	17	0	17	4
50.10.10.11	PERFORMANCE EVALUATION	USER	SYS ENGR	3	1	3	4	3
50.10.10.12	PERFORMANCE EVALUATION	IC	SYS ENGR	16	1	3	4	3
50.10.10.13	PERFORMANCE EVALUATION	LS	SYS ENGR	3	3	0	3	4
50.10.10.14	PERFORMANCE EVALUATION	USER	SYS ENGR	1	18	0	18	4
50.10.10.15	PERFORMANCE EVALUATION	IC	SYS ENGR	4	18	0	18	4
50.10.10.16	PERFORMANCE EVALUATION	LS	SYS ENGR	1	18	0	18	4
50.10.10.21	EXPENDABLES LOADS	USER	SYS ENGR	2	8	0	9	4
50.10.10.22	EXPENDABLES LOADS	IC	SYS ENGR	6	8	0	9	4
50.10.10.23	EXPENDABLES LOADS	LS	SYS ENGR	1	8	0	9	4
50.10.10.31	EMI	USER	SYS ENGR	1	2	0	2	4
50.10.10.32	EMI	IC	SYS ENGR	2	2	0	2	4
50.10.10.33	EMI	LS	SYS ENGR	1	2	0	2	4
50.10.20.11	FLIGHT AND GROUND REQUIREMENT	USER	SYS ENGR	4	2	3	5	3
50.10.20.12	FLIGHT AND GROUND REQUIREMENT	IC	SYS ENGR	8	2	3	5	3
50.10.30.11	TESTS, PARAMETERS LIMIT	USER	SYS ENGR	4	4	0	5	4
50.10.30.12	TESTS, PARAMETERS LIMIT	IC	SYS ENGR	12	4	0	5	4
50.10.30.13	TESTS, PARAMETERS LIMIT	LS	SYS ENGR	2	5	0	5	4
50.10.30.21	CONFIDENCE COST RISK	USER	SYS ENGR	1	5	0	5	4
50.10.30.22	CONFIDENCE COST RISK	IC	SYS ENGR	2	5	0	5	4
50.10.40.11	GSE FACILITY REQUIREMENTS	USER	SYS ENGR	1	9	0	9	4
50.10.40.12	GSE FACILITY REQUIREMENTS	IC	SYS ENGR	2	9	0	9	4
50.20.10.11	SYSTEM OPERATING INSTRUCTIONS	USER	DESIGNER	10	7	10	13	3
50.20.10.12	SYSTEM OPERATING INSTRUCTIONS	IC	DESIGNER	10	7	10	13	3
50.20.10.21	EQUIPMENT SPECIFICATIONS	USER	DESIGNER	10	6	8	10	3
50.20.10.22	EQUIPMENT SPECIFICATIONS	IC	DESIGNER	10	6	8	10	3
50.20.10.31	CPSE COORDINATION	USER	DESIGNER	3	6	8	12	2
50.20.10.32	CPSE COORDINATION	IC	DESIGNER	3	6	8	12	2
50.20.10.33	CPSE COORDINATION	LS	DESIGNER	2	8	0	9	4
50.20.20.11	LAYOUT AND INSTALLATION	IC	DESIGNER	12	7	9	12	3
50.20.20.12	LAYOUT AND INSTALLATION	LS	DESIGNER	1	7	9	12	3
50.20.20.21	INTERFACE HARDWARE	IC	DESIGNER	13	7	9	12	3
50.20.20.31	TURNAROUND REFURBISHMENT PLAN	IC	DESIGNER	3	8	0	9	4
50.20.20.32	TURNAROUND REFURBISHMENT PLAN	USER	DESIGNER	1	8	0	9	4
50.20.30.11	ICDS	USER	DESIGNER	1	6	0	9	4
50.20.30.12	ICDS	IC	DESIGNER	2	6	0	9	4
50.20.30.13	ICDS	LS	DESIGNER	1	6	0	9	4
50.20.40.11	COST COMMONALITY ANALYSIS	USER	DESIGNER	1	5	0	5	4
50.20.40.12	COST COMMONALITY ANALYSIS	IC	DESIGNER	1	5	0	5	4
50.20.40.13	COST COMMONALITY ANALYSIS	LS	DESIGNER	1	5	0	5	4
50.30.10.11	ORBITER MISSION MODIFICATIONS	USER	PROGRAMMER	2	6	0	7	4
50.30.10.12	ORBITER MISSION MODIFICATIONS	IC	PROGRAMMER	2	6	0	7	4
50.30.10.13	ORBITER MISSION MODIFICATIONS	LS	PROGRAMMER	1	6	0	7	4
50.30.10.21	SL AND EXPERIMENT SOFTWARE REQMTS	USER	PROGRAMMER	4	5	7	8	2
50.30.10.22	SL AND EXPERIMENT SOFTWARE REQMTS	IC	PROGRAMMER	4	5	7	8	2
50.30.20.11	FLIGHT OPERATIONS	IC	PROGRAMMER	12	7	12	14	2
50.30.20.12	FLIGHT OPERATIONS	IC	CODER	2	7	12	14	2
50.30.20.21	CHECKOUT & PERFORMANCE MONITOR	IC	PROGRAMMER	8	8	9	12	2
50.30.20.22	CHECKOUT & PERFORMANCE MONITOR	IC	CODER	4	8	9	12	2
50.30.20.41	REPAIR REFURBISHMENT	USER	PROGRAMMER	1	18	0	18	4
50.30.20.42	REPAIR REFURBISHMENT	IC	PROGRAMMER	2	18	0	18	4
50.40.21.	RELIABILITY ANALYSIS	USER	SYS ENGR	2	4	5	6	2
50.40.22.	RELIABILITY ANALYSIS	IC	SYS ENGR	5	4	5	6	2
50.40.31.	QC INSPECTION	IC	SYS ENGR	1	13	0	17	4
50.50.21.	SAFETY ANALYSIS	USER	SYS ENGR	2	3	0	4	4
50.50.22.	SAFETY ANALYSIS	IC	SYS ENGR	6	3	0	4	4
50.50.23.	SAFETY ANALYSIS	LS	SYS ENGR	2	4	0	4	4

Table 3.1-2. Concept I Supporting Function Task Estimates (Cont)

WBS NO.	TASK TITLE	CENTER	SKILL CODE	MAN MONTHS	SPREAD OPTION			
					BEGIN	PEAK	END	TYPE
50.50.31.	SAFETY REVIEWS	USER	SYS ENGR	2	8	9	10	2
50.50.32.	SAFETY REVIEWS	IC	SYS ENGR	2	8	9	10	3
50.50.33.	SAFETY REVIEWS	LS	SYS ENGR	1	9	0	11	4
50.60.11.	MOCKUPS	USER	DESIGNER	2	9	10	11	3
50.60.12.	MOCKUPS	IC	DESIGNER	6	9	10	11	3
50.60.14.	MOCKUPS	LS	MECHANIC	4	9	0	11	4
50.80.11.	CONFIGURATION CONTROL	USER	SYS ENGR	3	8	0	17	4
50.80.12.	CONFIGURATION CONTROL	IC	SYS ENGR	12	8	0	17	4
50.80.13.	CONFIGURATION CONTROL	LS	SYS ENGR	3	8	0	17	4
60.10.11.	CABLES AND WIRING	IC	DESIGNER	8	8	9	12	3
60.10.12.	CABLES AND WIRING	IC	MECHANIC	8	8	9	12	3
60.10.21.	STRUCTURES	IC	DESIGNER	10	8	9	12	3
60.10.22.	STRUCTURES	IC	MECHANIC	13	8	9	12	3
60.10.31.	PROTECTIVE ENCLOSURE	IC	DESIGNER	2	9	0	12	4
60.10.32.	PROTECTIVE ENCLOSURE	IC	MECHANIC	1	9	0	12	4
60.20.11.	LEVEL III TEST PLANS	USER	TEST ENGR	6	10	11	12	3
60.20.12.	LEVEL III TEST PLANS	IC	TEST ENGR	30	10	11	12	3
60.20.21.	LEVEL III TEST REPORTS	IC	TEST ENGR	4	11	15	15	2
63.20.11.	LEVEL II TEST PLANS	IC	TEST ENGR	5	11	12	13	2
63.20.21.	LEVEL II TEST REPORTS	IC	TEST ENGR	2	15	0	16	4
66.20.11.	LEVEL I TEST PLANS	IC	TEST ENGR	5	11	12	13	2
66.20.12.	LEVEL I TEST PLANS	LS	TEST ENGR	4	11	12	13	2
66.20.21.	LEVEL I TEST REPORTS	IC	TEST ENGR	1	17	0	17	4
66.20.22.	LEVEL I TEST REPORTS	LS	TEST ENGR	1	17	0	17	4
66.40.11.	LEVEL I SAFETY REVIEW	USER	SYS ENGR	1	17	0	17	4
66.40.12.	LEVEL I SAFETY REVIEW	IC	SYS ENGR	1	17	0	17	4
66.40.13.	LEVEL I SAFETY REVIEW	LS	SYS ENGR	1				
70.10.11.	SPECIAL TEST EQUIPMENT	IC	DESIGNER	1	9	0	10	4
70.10.12.	SPECIAL TEST EQUIPMENT	IC	TEST ENGR	1	9	0	10	4
70.10.13.	SPECIAL TEST EQUIPMENT	IC	MECHANIC	2	9	0	10	4

Table 3.1-3. Concept II Supporting Function Task Estimates

WBS NO.	TASK TITLE	CENTER	SKILL CODE	MAN MONTHS	SPREAD OPTION BEGIN	PEAK	END	TYPE
30.10.11.	EXPERIMENT REQUIREMENT	USER	OPS ANALYST	8	1	0	2	4
30.10.21.	ORBIT TRAJECTORY ANALYSIS	IC	OPS ANALYST	2	1	0	1	4
30.10.31.	MISSION TIMELINES	IC	OPS ANALYST	1	18	0	18	4
30.10.32.	MISSION TIMELINES	IC	OPS ANALYST	4	2	0	3	4
30.20.11.	OPERATIONS PLANNING	IC	OPS ANALYST	3	1	1	4	3
30.20.12.	OPERATIONS PLANNING	LS	OPS ANALYST	1	2	0	3	4
30.20.13.	OPERATIONS PLANNING	IC	OPS ANALYST	1	18	0	18	4
30.20.21.	RESOURCE ALLOCATION	IC	OPS ANALYST	3	2	2	5	3
30.20.22.	RESOURCE ALLOCATION	LS	OPS ANALYST	1	2	0	3	4
30.20.23.	RESOURCE ALLOCATION	IC	OPS ANALYST	1	18	0	18	4
30.20.31.	CREW TASK TIMELINES	IC	OPS ANALYST	5	3	0	5	4
30.20.32.	CREW TASK TIMELINES	LS	OPS ANALYST	1	3	0	5	4
30.20.41.	CREW SKILLS	IC	OPS ANALYST	2	1	0	1	4
30.30.11.	MISSION PLANS	USER	OPS ANALYST	2	9	0	10	4
30.30.12.	MISSION PLANS	IC	OPS ANALYST	3	9	0	10	4
30.30.13.	MISSION PLANS	LS	OPS ANALYST	1	9	0	10	4
30.30.21.	MISSION OPERATING INSTRUCTIONS	USER	OPS ANALYST	4	10	11	13	3
30.30.22.	MISSION OPERATING INSTRUCTIONS	IC	OPS ANALYST	7	10	11	13	3
30.30.23.	MISSION OPERATING INSTRUCTIONS	LS	OPS ANALYST	1	11	0	11	4
30.30.31.	GROUND SUPPORT PLANS	USER	OPS ANALYST	4	4	0	5	4
30.30.32.	GROUND SUPPORT PLANS	IC	OPS ANALYST	4	4	0	5	4
30.30.33.	GROUND SUPPORT PLANS	LS	OPS ANALYST	1	5	0	5	4
30.40.11.	EXPERIMENT FLIGHT DATA ANALYSIS	USER	SYS ENGR	2	18	0	18	4
30.40.21.	REPORT PREPARATION	USER	SYS ENGR	1	18	0	18	4
30.40.22.	REPORT PREPARATION	IC	SYS ENGR	1	18	0	18	4
30.40.23.	REPORT PREPARATION	LS	SYS ENGR	1	18	0	18	4
30.50.11.	TRAINING PLANS AND PROCEDURES	USER	OPS ANALYST	2	4	0	4	4
30.50.12.	TRAINING PLANS AND PROCEDURES	IC	OPS ANALYST	3	4	0	4	4
30.50.13.	TRAINING PLANS AND PROCEDURES	LS	OPS ANALYST	1	4	0	4	4
30.50.21.	TRAINING ACTIVITY	USER	SYS ENGR	2	10	0	11	4
30.50.22.	TRAINING ACTIVITY	IC	SYS ENGR	4	10	0	11	4
30.50.23.	TRAINING ACTIVITY	LS	SYS ENGR	2	10	0	10	4
40.10.11.	MISSION CONTROL	USER	OPS ANALYST	1	17	0	17	4
40.10.12.	MISSION CONTROL	IC	OPS ANALYST	2	17	0	17	4
40.10.13.	MISSION CONTROL	LS	OPS ANALYST	2	17	0	17	4
40.20.11.	OPERATIONS MONITOR RM	USER	SYS ENGR	3	17	0	17	4
40.20.12.	OPERATIONS MONITOR RM	IC	SYS ENGR	1	17	0	17	4
40.20.13.	OPERATIONS MONITOR RM	LS	SYS ENGR	3	17	0	17	4
40.20.21.	DATA TRANSMISSION	USER	MECHANIC	1	17	0	17	4
40.20.22.	DATA TRANSMISSION	IC	MECHANIC	1	17	0	17	4
40.30.11.	GROUND TRUTH SITE	USER	OPS ANALYST	24	3	13	18	3
40.30.12.	GROUND TRUTH SITE	IC	OPS ANALYST	12	3	13	18	3
40.30.13.	GROUND TRUTH SITE	USER	SYS ENGR	24	3	13	18	3
40.30.14.	GROUND TRUTH SITE	IC	SYS ENGR	12	3	13	18	3
40.30.21.	SPACELAB SUBSYSTEMS SUPPORT	IC	SYS ENGR	4	17	0	17	4
40.30.22.	SPACELAB SUBSYSTEMS SUPPORT	LS	SYS ENGR	4	17	0	17	4
50.10.10.11	PERFORMANCE EVALUATION	USER	SYS ENGR	3	1	3	4	3
50.10.10.12	PERFORMANCE EVALUATION	IC	SYS ENGR	16	1	3	4	3
50.10.10.13	PERFORMANCE EVALUATION	LS	SYS ENGR	4	1	3	4	3
50.10.10.14	PERFORMANCE EVALUATION	USER	SYS ENGR	1	18	0	18	4
50.10.10.15	PERFORMANCE EVALUATION	IC	SYS ENGR	4	18	0	18	4
50.10.10.16	PERFORMANCE EVALUATION	LS	SYS ENGR	1	18	0	18	4
50.10.10.21	EXPENDABLES LOADS	USER	SYS ENGR	2	8	0	9	4
50.10.10.22	EXPENDABLES LOADS	IC	SYS ENGR	6	8	0	7	4
50.10.10.23	EXPENDABLES LOADS	LS	SYS ENGR	1	8	0	9	4
50.10.10.31	EMI	USER	SYS ENGR	1	2	0	2	4
50.10.10.32	EMI	IC	SYS ENGR	2	2	0	2	4
50.10.10.33	EMI	LS	SYS ENGR	1	2	0	2	4
50.10.20.11	FLIGHT AND GROUND REQUIREMENTS	USER	SYS ENGR	4	2	3	5	2
50.10.20.12	FLIGHT AND GROUND REQUIREMENTS	IC	SYS ENGR	6	2	4	5	2
50.10.20.13	FLIGHT AND GROUND REQUIREMENTS	LS	SYS ENGR	2	4	0	4	4
50.10.30.11	TESTS, PARAMETERS AND LIMIT	USER	SYS ENGR	4	4	5	5	4
50.10.30.12	TESTS, PARAMETERS AND LIMIT	IC	SYS ENGR	10	4	5	5	4
50.10.30.13	TESTS, PARAMETERS AND LIMIT	LS	SYS ENGR	4	5	0	5	4
50.10.30.21	CONFIDENCE COST RISK	USER	SYS ENGR	1	5	0	5	4
50.10.30.22	CONFIDENCE COST RISK	IC	SYS ENGR	1	5	0	5	4
50.10.30.23	CONFIDENCE COST RISK	LS	SYS ENGR	1	5	0	5	4
50.10.40.11	GSE FACILITY REQUIREMENTS	USER	SYS ENGR	1	9	0	9	4
50.10.40.12	GSE FACILITY REQUIREMENTS	IC	SYS ENGR	1	9	0	9	4
50.10.40.13	GSE FACILITY REQUIREMENTS	LS	SYS ENGR	1	9	0	9	4
50.20.10.11	SYSTEM OPERATING INSTRUCTIONS	USER	DESIGNER	10	7	10	13	3
50.20.10.12	SYSTEM OPERATING INSTRUCTIONS	IC	DESIGNER	10	7	10	13	3
50.20.10.13	SYSTEM OPERATING INSTRUCTIONS	LS	DESIGNER	1	7	10	13	3
50.20.10.21	EQUIPMENT SPECIFICATIONS	USER	DESIGNER	10	6	8	10	3
50.20.10.22	EQUIPMENT SPECIFICATIONS	IC	DESIGNER	10	6	8	10	3
50.20.10.23	EQUIPMENT SPECIFICATIONS	LS	DESIGNER	1	8	0	9	4
50.20.10.31	CPSE COORDINATION	USER	DESIGNER	3	6	8	12	3
50.20.10.32	CPSE COORDINATION	IC	DESIGNER	2	6	8	12	3
50.20.10.33	CPSE COORDINATION	LS	DESIGNER	3	8	0	9	4
50.20.20.11	LAYOUT AND INSTALLATION	IC	DESIGNER	12	3	9	12	3
50.20.20.12	LAYOUT AND INSTALLATION	LS	DESIGNER	2	8	0	8	4
50.20.20.21	INTERFACE HARDWARE	IC	DESIGNER	13	3	9	12	3
50.20.20.22	INTERFACE HARDWARE	LS	DESIGNER	1	8	0	8	4
50.20.20.31	TURNAROUND REFURBISHMENT PLAN	USER	DESIGNER	1	8	0	9	4
50.20.20.32	TURNAROUND REFURBISHMENT PLAN	IC	DESIGNER	2	8	0	9	4
50.20.20.33	TURNAROUND REFURBISHMENT PLAN	LS	DESIGNER	1	8	0	9	4
50.20.30.11	ICDS	USER	DESIGNER	1	6	0	9	4
50.20.30.12	ICDS	IC	DESIGNER	3	6	0	9	4
50.20.30.13	ICDS	LS	DESIGNER	2	5	0	9	4
50.20.40.11	COST COMMONALITY ANALYSIS	USER	DESIGNER	1	5	0	5	4
50.20.40.12	COST COMMONALITY ANALYSIS	IC	DESIGNER	1	5	0	5	4
50.20.40.13	COST COMMONALITY ANALYSIS	LS	DESIGNER	1	5	0	5	4
50.30.10.11	ORBITER MISSION MODS	USER	PROGRAMMER	2	6	0	7	4
50.30.10.12	ORBITER MISSION MODS	IC	PROGRAMMER	2	6	0	7	4
50.30.10.13	ORBITER MISSION MODS	LS	PROGRAMMER	2	6	0	7	4
50.30.10.21	SPACELAB & EXPERIMENT SOFTWARE REQMTS	USER	PROGRAMMER	4	5	7	8	2
50.30.10.22	SPACELAB & EXPERIMENT SOFTWARE REQMTS	IC	PROGRAMMER	4	5	7	8	2
50.30.10.23	SPACELAB & EXPERIMENT SOFTWARE REQMTS	LS	PROGRAMMER	2	5	7	8	2

Table 3.1-3. Concept II Supporting Function Task Estimates (Cont)

WBS NO.	TASK TITLE	CENTER	SKILL CODE	MAN MONTHS	SPREAD OPTION			
					BEGIN	PEAK	END	TYPE
50.30.20.11	FLIGHT OPERATIONS	IC	PROGRAMMER	12	7	12	14	2
50.30.20.12	FLIGHT OPERATIONS	IC	CODER	2	7	12	14	2
50.30.20.21	CHECKOUT AND PERFORMANCE MONITOR	IC	PROGRAMMER	8	8	9	12	2
50.30.20.22	CHECKOUT AND PERFORMANCE MONITOR	IC	CODER	4	8	9	12	2
50.30.20.41	REPAIR REFURBISHMENT	USER	DESIGNER	1	18	0	18	4
50.30.20.42	REPAIR REFURBISHMENT	IC	DESIGNER	1	18	0	18	4
50.30.20.43	REPAIR REFURBISHMENT	LS	DESIGNER	1	18	0	18	4
50.40.21.	RELIABILITY ANALYSIS	USER	SYS ENGR	2	4	5	6	2
50.40.22.	RELIABILITY ANALYSIS	IC	SYS ENGR	3	4	5	6	2
50.40.23.	RELIABILITY ANALYSIS	LS	SYS ENGR	1	5	0	5	4
50.40.31.	QC INSPECTION	IC	SYS ENGR	1	13	0	17	4
50.40.32.	QC INSPECTION	LS	SYS ENGR	1	15	0	17	4
50.50.21.	SAFETY ANALYSIS	USER	SYS ENGR	2	3	0	4	4
50.50.22.	SAFETY ANALYSIS	IC	SYS ENGR	5	3	0	4	4
50.50.23.	SAFETY ANALYSIS	LS	SYS ENGR	3	4	0	4	4
50.50.31.	SAFETY REVIEWS	USER	SYS ENGR	2	8	9	10	2
50.50.32.	SAFETY REVIEWS	IC	SYS ENGR	2	8	9	10	2
50.50.33.	SAFETY REVIEWS	LS	SYS ENGR	1	9	0	11	4
50.60.11.	MOCKUPS	USER	DESIGNER	2	9	10	11	3
50.60.12.	MOCKUPS	IC	DESIGNER	6	9	10	11	3
50.60.15.	MOCKUPS	IC	MECHANIC	4	9	0	11	4
50.80.11.	CONFIGURATION CONTROL	USER	SYS ENGR	3	8	0	17	4
50.80.12.	CONFIGURATION CONTROL	IC	SYS ENGR	9	8	0	17	4
50.80.13.	CONFIGURATION CONTROL	LS	SYS ENGR	6	8	0	17	4
60.10.11.	CABLES AND WIRING	IC	DESIGNER	8	8	9	12	3
60.10.12.	CABLES AND WIRING	IC	MECHANIC	8	8	9	12	3
60.10.21.	STRUCTURES	IC	DESIGNER	10	8	9	12	3
60.10.22.	STRUCTURES	IC	MECHANIC	13	8	9	12	3
60.10.31.	PROTECTIVE ENCLOSURE	IC	DESIGNER	2	9	0	12	4
60.10.32.	PROTECTIVE ENCLOSURE	IC	MECHANIC	1	9	0	12	4
60.20.11.	LEVEL III TEST PLANS	USER	TEST ENGR	6	10	11	12	2
60.20.12.	LEVEL III TEST PLANS	IC	TEST ENGR	30	10	11	12	2
60.20.21.	LEVEL III TEST REPORTS	IC	TEST ENGR	4	13	15	15	2
63.20.11.	LEVEL II TEST PLANS	IC	TEST ENGR	4	11	12	13	2
63.20.12.	LEVEL II TEST PLANS	LS	TEST ENGR	2	11	12	13	2
63.20.21.	LEVEL II TEST REPORTS	IC	TEST ENGR	1	15	0	16	4
63.20.22.	LEVEL II TEST REPORTS	LS	TEST ENGR	2	15	0	16	4
66.20.11.	LEVEL I TEST PLANS	IC	TEST ENGR	5	11	12	13	2
66.20.12.	LEVEL I TEST PLANS	LS	TEST ENGR	4	11	12	13	2
66.20.21.	LEVEL I TEST REPORTS	IC	TEST ENGR	1	17	0	17	4
66.20.22.	LEVEL I TEST REPORTS	LS	TEST ENGR	1	17	0	17	4
66.40.11.	LEVEL I SAFETY REVIEW	USER	SYS ENGR	1	17	0	17	4
66.40.12.	LEVEL I SAFETY REVIEW	IC	SYS ENGR	1	17	0	17	4
66.40.13.	LEVEL I SAFETY REVIEW	LS	SYS ENGR	1	17	0	17	4
70.10.11.	SPECIAL TEST EQUIPMENT	IC	DESIGNER	1	9	0	10	4
70.10.13.	SPECIAL TEST EQUIPMENT	IC	TEST ENGR	1	9	0	10	4
70.10.15.	SPECIAL TEST EQUIPMENT	IC	MECHANIC	2	9	0	10	4

Table 3.1-4. Concept III Supporting Function Task Estimates

WBS NO.	TASK TITLE	CENTER	SKILL CODE	MAN MONTHS	SPREAD OPTION			
					BEGIN	PEAK	END	TYPE
30.10.11.	EXPERIMENT REQUIREMENT	USER	OPS ANALYST	8	1	0	2	4
30.10.21.	ORBIT TRAJECTORY ANALYSIS	USER	OPS ANALYST	2	1	0	1	4
30.10.31.	MISSION TIMELINES	USER	OPS ANALYST	1	18	0	18	4
30.10.32.	MISSION TIMELINES	USER	OPS ANALYST	4	2	0	3	4
30.20.11.	OPERATIONS PLANNING	LS	OPS ANALYST	1	2	0	3	4
30.20.13.	OPERATIONS PLANNING	USER	OPS ANALYST	1	18	0	18	4
30.20.12.	OPERATIONS PLANNING	USER	OPS ANALYST	3	1	1	4	3
30.20.21.	RESOURCE ALLOCATION	LS	OPS ANALYST	1	2	0	3	4
30.20.22.	RESOURCE ALLOCATION	USER	OPS ANALYST	3	2	2	5	3
30.20.23.	RESOURCE ALLOCATION	USER	OPS ANALYST	1	18	0	18	4
30.20.31.	CREW TASK TIMELINES	USER	OPS ANALYST	5	3	0	5	4
30.20.32.	CREW TASK TIMELINES	LS	OPS ANALYST	1	3	0	5	4
30.20.41.	CREW SKILLS	USER	OPS ANALYST	2	1	0	1	4
30.30.11.	MISSION PLANS	USER	OPS ANALYST	4	9	0	10	4
30.30.12.	MISSION PLANS	LS	OPS ANALYST	1	9	0	10	4
30.30.21.	MISSION OPERATING INSTRUCTIONS	USER	OPS ANALYST	12	10	11	13	3
30.30.22.	MISSION OPERATING INSTRUCTIONS	LS	OPS ANALYST	1	11	0	11	4
30.30.31.	GROUND SUPPORT PLANS	USER	OPS ANALYST	5	4	0	5	4
30.30.32.	GROUND SUPPORT PLANS	LS	OPS ANALYST	1	5	0	5	4
30.40.11.	EXPERIMENT FLIGHT DATA ANALYSIS	USER	SYS ENGR	2	18	0	19	4
30.40.21.	REPORT PREPARATION	USER	SYS ENGR	1	18	0	18	4
30.40.22.	REPORT PREPARATION	LS	SYS ENGR	1	18	0	18	4
30.50.11.	TRAINING PLANS AND PROCEDURES	USER	OPS ANALYST	2	4	0	4	4
30.50.12.	TRAINING PLANS AND PROCEDURES	LS	OPS ANALYST	1	4	0	4	4
30.50.31.	TRAINING ACTIVITY	USER	SYS ENGR	6	10	0	11	4
30.50.32.	TRAINING ACTIVITY	LS	SYS ENGR	2	10	0	10	4
40.10.11.	MISSION CONTROL	USER	OPS ANALYST	2	17	0	17	4
40.10.13.	MISSION CONTROL	LS	OPS ANALYST	2	17	0	17	4
40.20.11.	OPERATIONS MONITOR RM	USER	SYS ENGR	4	17	0	17	4
40.20.13.	OPERATIONS MONITOR RM	LS	SYS ENGR	3	17	0	17	4
40.20.21.	DATA TRANSMISSION	USER	MECHANIC	1	17	0	17	4
40.30.11.	GROUND TRUTH SITE	USER	OPS ANALYST	36	3	13	18	3
40.30.12.	GROUND TRUTH SITE	USER	SYS ENGR	36	3	13	18	3
40.30.31.	SPACELAB SUBSYSTEMS SUPPORT	USER	SYS ENGR	4	17	0	17	4
40.30.32.	SPACELAB SUBSYSTEMS SUPPORT	LS	SYS ENGR	4	17	0	17	4
50.10.10.11	PERFORMANCE EVALUATION	USER	SYS ENGR	16	1	3	4	3
50.10.10.12	PERFORMANCE EVALUATION	USER	SYS ENGR	6	18	0	18	4
50.10.10.13	PERFORMANCE EVALUATION	LS	SYS ENGR	4	1	3	4	3
50.10.10.14	PERFORMANCE EVALUATION	LS	SYS ENGR	1	18	0	18	4
50.10.10.15	PERFORMANCE EVALUATION	IC	SYS ENGR	4	1	3	4	3
50.10.10.16	PERFORMANCE EVALUATION	IC	SYS ENGR	1	18	0	18	4
50.10.10.21	EXPENDABLES LOAD	USER	SYS ENGR	6	8	0	9	4
50.10.10.22	EXPENDABLES LOAD	IC	SYS ENGR	2	8	0	9	4
50.10.10.23	EXPENDABLES LOAD	LS	SYS ENGR	1	8	0	9	4
50.10.10.31	EMI	USER	SYS ENGR	2	2	0	2	4
50.10.10.32	EMI	IC	SYS ENGR	1	2	0	2	4
50.10.10.33	EMI	LS	SYS ENGR	1	2	0	2	4
50.10.20.11	FLIGHT AND GROUND REQUIREMENTS	USER	SYS ENGR	10	2	3	5	3
50.10.20.12	FLIGHT AND GROUND REQUIREMENTS	LS	SYS ENGR	2	4	0	4	4
50.10.30.11	TESTS, PARAMETERS AND LIMITS	USER	SYS ENGR	12	4	5	5	4
50.10.30.12	TESTS, PARAMETERS AND LIMITS	IC	SYS ENGR	2	4	5	5	4
50.10.30.13	TESTS, PARAMETERS AND LIMITS	LS	SYS ENGR	4	5	0	5	4
50.10.30.21	CONFIDENCE COST RISK	USER	SYS ENGR	2	5	0	5	4
50.10.30.22	CONFIDENCE COST RISK	LS	SYS ENGR	1	5	0	5	4
50.10.40.11	GSE FACILITY REQUIREMENTS	USER	SYS ENGR	1	9	0	9	4
50.10.40.12	GSE FACILITY REQUIREMENTS	IC	SYS ENGR	1	9	0	9	4
50.10.40.13	GSE FACILITY REQUIREMENTS	LS	SYS ENGR	1	9	0	9	4
50.20.10.11	SYSTEM OPERATING INSTRUCTIONS	USER	DESIGNER	20	7	10	13	3
50.20.10.12	SYSTEM OPERATING INSTRUCTIONS	IC	DESIGNER	1	7	10	13	3
50.20.10.13	SYSTEM OPERATING INSTRUCTIONS	LS	DESIGNER	1	7	10	13	3
50.20.10.21	EQUIPMENT SPECIFICATIONS	USER	DESIGNER	20	6	8	10	3
50.20.10.22	EQUIPMENT SPECIFICATIONS	IC	DESIGNER	4	6	8	10	3
50.20.10.23	EQUIPMENT SPECIFICATIONS	LS	DESIGNER	1	6	8	10	3
50.20.10.31	CPSE COORDINATION	USER	DESIGNER	5	6	8	12	3
50.20.10.32	CPSE COORDINATION	IC	DESIGNER	1	6	8	12	3
50.20.10.33	CPSE COORDINATION	LS	DESIGNER	3	8	0	9	4
50.20.20.11	LAYOUT AND INSTALLATION	IC	DESIGNER	12	7	9	12	3
50.20.20.12	LAYOUT AND INSTALLATION	LS	DESIGNER	2	8	0	8	4
50.20.20 21	INTERFACE HARDWARE	IC	DESIGNER	13	7	9	12	3
50.20.20 22	INTERFACE HARDWARE	LS	DESIGNER	1	8	0	9	4
50.20.20.31	TURNAROUND REFURBISHMENT PLAN	USER	DESIGNER	2	8	0	9	4
50.20.20.32	TURNAROUND REFURBISHMENT PLAN	IC	DESIGNER	1	8	0	9	4
50.20.20.33	TURNAROUND REFURBISHMENT PLAN	LS	DESIGNER	1	8	0	9	4
50.20.30.11	ICDS	USER	DESIGNER	2	6	0	9	4
50.20.30.12	ICDS	LS	DESIGNER	2	6	0	9	4
50.20.41.	COST COMMONALITY ANALYSIS	USER	DESIGNER	1	5	0	5	4
50.20.42.	COST COMMONALITY ANALYSIS	IC	DESIGNER	1	5	0	5	4
50.20.43.	COST COMMONALITY ANALYSIS	LS	DESIGNER	1	5	0	5	4
50.30.10.11	ORBITER MISSION MODS	USER	PROGRAMMER	2	6	0	7	4
50.30.10.12	ORBITER MISSION MODS	LS	PROGRAMMER	2	6	0	7	4
50.30.10.21	SPACELAB & EXPERIMENT SOFTWARE REQMTS	USER	PROGRAMMER	6	5	7	8	3
50.30.10.22	SPACELAB & EXPERIMENT SOFTWARE REQMTS	LS	PROGRAMMER	2	5	7	8	3
50.30.20.11	FLIGHT OPERATIONS	USER	PROGRAMMER	12	7	12	14	2
50.30.20.12	FLIGHT OPERATIONS	USER	CODER	2	7	12	14	2
50.30.20.21	CHECKOUT AND PERFORMANCE MONITOR	USER	PROGRAMMER	8	8	9	12	2
50.30.20.22	CHECKOUT AND PERFORMANCE MONITOR	USER	CODER	4	8	9	12	2
50.30.20.41	REPAIR REFURBISHMENT	USER	DESIGNER	1	18	0	18	4
50.30.20.42	REPAIR REFURBISHMENT	IC	DESIGNER	1	18	0	18	4
50.30.20.43	REPAIR REFURBISHMENT	LS	DESIGNER	1	18	0	18	4
50.40.21.	RELIABILITY ANALYSIS	USER	SYS ENGR	5	4	5	6	3
50.40.22.	RELIABILITY ANALYSIS	IC	SYS ENGR	1	4	5	6	3
50.40.23.	RELIABILITY ANALYSIS	LS	SYS ENGR	1	5	0	5	4
50.40.31.	QC INSPECTION	USER	SYS ENGR	1	13	0	17	4
50.40.33.	QC INSPECTION	LS	SYS ENGR	1	15	0	17	4
50.50.21.	SAFETY ANALYSIS	USER	SYS ENGR	6	3	0	4	4
50.50.22.	SAFETY ANALYSIS	IC	SYS ENGR	1	3	0	4	4
50.50.23.	SAFETY ANALYSIS	LS	SYS ENGR	3	4	0	4	4
50.50.31.	SAFETY REVIEWS	USER	SYS ENGR	2	8	9	10	2
50.50.32.	SAFETY REVIEWS	IC	SYS ENGR	2	8	9	10	2
50.50.33.	SAFETY REVIEWS	LS	SYS ENGR	1	9	0	11	4

Table 3.1-4. Concept III Supporting Function Task Estimates (Cont)

WBS NO.	TASK TITLE	CENTER	SKILL CODE	MAN MONTHS				
					BEGIN	PEAK	END	TYPE
50.60.11.	MOCKUPS	USER	DESIGNER	6	9	10	11	3
50.60.13.	MOCKUPS	USER	MECHANIC	4	9	10	11	4
50.80.11.	CONFIGURATION CONTROL	USER	SYS ENGR	9	8	0	17	4
50.80.12.	CONFIGURATION CONTROL	IC	SYS ENGR	3	8	0	17	4
50.80.13.	CONFIGURATION CONTROL	LS	SYS ENGR	6	8	0	17	4
60.10.11.	CABLES AND WIRING	IC	DESIGNER	8	8	9	12	3
60.10.12.	CABLES AND WIRING	IC	MECHANIC	8	8	9	12	3
60.10.21.	STRUCTURES	IC	DESIGNER	10	8	9	12	3
60.10.22.	STRUCTURES	IC	MECHANIC	13	8	9	12	3
60.10.31.	PROTECTIVE ENCLOSURES	IC	DESIGNER	2	9	0	12	4
60.10.32.	PROTECTIVE ENCLOSURES	IC	MECHANIC	1	9	0	12	4
60.20.11.	LEVEL III TEST PLANS	USER	TEST ENGR	30	10	11	12	3
60.20.12.	LEVEL III TEST PLANS	IC	TEST ENGR	2	10	11	12	3
60.20.21.	LEVEL III TEST REPORTS	USER	TEST ENGR	4	13	15	15	2
60.20.22.	LEVEL III TEST REPORTS	IC	TEST ENGR	1	13	15	15	2
63.20.11.	LEVEL II TEST PLANS	USER	TEST ENGR	4	11	12	13	2
63.20.12.	LEVEL II TEST PLANS	LS	TEST ENGR	2	11	12	13	2
63.20.21.	LEVEL II TEST REPORTS	USER	TEST ENGR	1	15	0	16	4
63.20.22.	LEVEL II TEST REPORTS	LS	TEST ENGR	2	15	0	16	4
66.20.11.	LEVEL I TEST PLANS	USER	TEST ENGR	5	11	12	13	2
66.20.12.	LEVEL I TEST PLANS	LS	TEST ENGR	4	11	12	13	2
66.20.21.	LEVEL I TEST REPORTS	USER	TEST ENGR	1	17	0	17	4
66.20.22.	LEVEL I TEST REPORTS	LS	TEST ENGR	1	17	0	17	4
66.40.11.	LEVEL I SAFETY REVIEW	USER	SYS ENGR	1	17	0	17	4
66.40.13.	LEVEL I SAFETY REVIEW	LS	SYS ENGR	1	17	0	17	4
70.10.13.	SPECIAL TEST EQUIPMENT	USER	DESIGNER	1	9	0	10	4
70.10.15.	SPECIAL TEST EQUIPMENT	USER	MECHANIC	2	9	0	10	4
70.10.17.	SPECIAL TEST EQUIPMENT	USER	TEST ENGR	1	9	0	10	4

Table 3.1-5. Concept IV Supporting Function Task Estimates

WBS NO.	TASK TITLE	CENTER	SKILL CODE	MAN MONTHS	SPREAD OPTION			
					BEGIN	PEAK	END	TYPE
30.10.11.	EXPERIMENT REQUIREMENT	USER	OPS ANALYST	8	1	0	2	4
30.10.21.	ORBIT TRAJECTORY ANALYSIS	USER	OPS ANALYST	2	1	0	1	4
30.10.31.	MISSION TIMELINES	USER	OPS ANALYST	1	18	0	18	4
30.10.32.	MISSION TIMELINES	USER	OPS ANALYST	4	2	0	3	4
30.20.11.	OPERATIONS PLANNING	USER	OPS ANALYST	3	1	1	4	3
30.20.12.	OPERATIONS PLANNING	LS	OPS ANALYST	1	2	0	3	4
30.20.13.	OPERATIONS PLANNING	USER	OPS ANALYST	1	18	0	18	4
30.20.21.	RESOURCE ALLOCATION	USER	OPS ANALYST	3	2	2	5	3
30.20.22.	RESOURCE ALLOCATION	LS	OPS ANALYST	1	2	0	3	4
30.20.23.	RESOURCE ALLOCATION	USER	OPS ANALYST	1	18	0	18	4
30.20.31.	CREW TASK TIMELINES	USER	OPS ANALYST	5	3	0	5	4
30.20.32.	CREW TASK TIMELINES	LS	OPS ANALYST	1	3	0	5	4
30.20.41.	CREW SKILLS	USER	OPS ANALYST	2	1	0	1	4
30.30.11.	MISSION PLANS	USER	OPS ANALYST	4	9	0	10	4
30.30.13.	MISSION PLANS	LS	OPS ANALYST	1	9	0	10	4
30.30.21.	MISSION OPERATING INSTRUCTIONS	USER	OPS ANALYST	12	10	11	13	3
30.30.23.	MISSION OPERATING INSTRUCTIONS	LS	OPS ANALYST	1	11	0	11	4
30.30.31.	GROUND SUPPORT PLANS	USER	OPS ANALYST	5	4	0	5	4
30.30.33.	GROUND SUPPORT PLANS	LS	OPS ANALYST	1	5	0	5	4
30.40.11.	EXPERIMENT FLIGHT DATA ANALYSIS	USER	SYS ENGR	2	18	0	18	4
30.40.21.	REPORT PREPARATION	USER	SYS ENGR	1	18	0	18	4
30.40.22.	REPORT PREPARATION	LS	SYS ENGR	1	18	0	18	4
30.50.11.	TRAINING PLANS AND PROCEDURES	USER	OPS ANALYST	2	4	0	4	4
30.50.12.	TRAINING PLANS AND PROCEDURES	LS	OPS ANALYST	1	4	0	4	4
30.50.31.	TRAINING ACTIVITY	USER	SYS ENGR	6	10	0	11	4
30.50.34.	TRAINING ACTIVITY	LS	SYS ENGR	2	10	0	10	4
40.10.11.	MISSION CONTROL	USER	OPS ANALYST	2	17	0	17	4
40.10.12.	MISSION CONTROL	LS	OPS ANALYST	2	17	0	17	4
40.20.11.	OPERATIONS MONITOR RM	USER	SYS ENGR	4	17	0	17	4
40.20.12.	OPERATIONS MONITOR RM	LS	SYS ENGR	3	17	0	17	4
40.20.21.	DATA TRANSMISSION	USER	MECHANIC	1	17	0	17	4
40.30.11.	GROUND TRUTH SITE	USER	OPS ANALYST	36	3	13	18	3
40.30.12.	GROUND TRUTH SITE	USER	SYS ENGR	36	3	13	18	3
40.30.31.	SPACELAB SUBSYSTEMS SUPPORT	LS	SYS ENGR	4	17	0	17	4
40.30.32.	SPACELAB SUBSYSTEMS SUPPORT	USER	SYS ENGR	4	17	0	17	4
50.10.10.11	PERFORMANCE EVALUATION	USER	SYS ENGR	16	1	3	4	3
50.10.10.12	PERFORMANCE EVALUATION	USER	SYS ENGR	6	18	0	18	4
50.10.10.13	PERFORMANCE EVALUATION	LS	SYS ENGR	4	1	3	4	3
50.10.10.14	PERFORMANCE EVALUATION	LS	SYS ENGR	1	18	0	18	4
50.10.10.21	EXPENDABLES LOADS	USER	SYS ENGR	8	8	0	9	4
50.10.10.23	EXPENDABLES LOADS	LS	SYS ENGR	1	8	0	9	4
50.10.10.31	EMI	USER	SYS ENGR	3	2	0	2	4
50.10.10.32	EMI	LS	SYS ENGR	1	2	0	2	4
50.10.21.	FLIGHT AND GROUND REQUIREMENTS	USER	SYS ENGR	10	2	3	5	2
50.10.23.	FLIGHT AND GROUND REQUIREMENTS	LS	SYS ENGR	2	4	0	4	4
50.10.30.11	TESTS, PARAMETERS AND LIMITS	USER	SYS ENGR	13	4	5	5	4
50.10.30.13	TESTS, PARAMETERS AND LIMITS	LS	SYS ENGR	4	5	0	5	4
50.10.30.21	CONFIDENCE COST RISK	USER	SYS ENGR	2	5	0	5	4
50.10.30.22	CONFIDENCE COST RISK	LS	SYS ENGR	1	5	0	5	4
50.10.40.11	GSE FACILITY REQUIREMENTS	USER	SYS ENGR	2	9	0	9	4
50.10.40;12	GSE FACILITY REQUIREMENTS	LS	SYS ENGR	1	9	0	9	4
50.20.10.11	SYSTEM OPERATING INSTRUCTIONS	USER	DESIGNER	20	7	10	13	3
50.10.10.13	SYSTEM OPERATING INSTRUCTIONS	LS	DESIGNER	1	7	10	13	3
50.20.10.21	EQUIPMENT SPECIFICATIONS	USER	DESIGNER	20	6	8	10	3
50.20.10.23	EQUIPMENT SPECIFICATIONS	LS	DESIGNER	1	6	8	10	3
50.20.10.31	CPSE COORDINATION	USER	DESIGNER	5	6	8	12	3
50.20.10.33	CPSE COORDINATION	LS	DESIGNER	3	8	0	9	4
50.20.20.11	LAYOUT AND INSTALLATION	USER	DESIGNER	12	7	9	12	3
50.20.20.13	LAYOUT AND INSTALLATION	LS.	DESIGNER	2	8	0	8	4
50.20.20.21	INTERFACE HARDWARE	USER	DESIGNER	13	7	9	12	3
50.20.20.23	INTERFACE HARDWARE	LS	DESIGNER	1	8	0	9	4
50.20.20.31	TURNAROUND REFURBISHMENT PLAN	USER	DESIGNER	3	8	0	9	4
50.20.20.33	TURNAROUND REFURBISHMENT PLAN	LS	DESIGNER	1	8	0	9	4
50.20.30.11	ICDS	USER	DESIGNER	2	6	0	9	4
50.20.30.12	ICDS	LS	DESIGNER	2	6	0	9	4
50.20.40.11	COST COMMONALITY ANALYSIS	USER	DESIGNER	2	5	0	5	4
50.20.40.12	COST COMMONALITY ANALYSIS	LS	DESIGNER	1	5	0	5	4
50.30.10.11	ORBITER MISSION MODS	USER	PROGRAMMER	2	6	0	7	4
50.30.10.12	ORBITER MISSION MODS	LS	PROGRAMMER	2	6	0	7	4
50.30.10.21	SPACELAB & EXPERIMENT SOFTWARE REQMTS	USER	PROGRAMMER	6	5	7	8	2
50.30.10.23	SPACELAB & EXPERIMENT SOFTWARE REQMTS	LS	PROGRAMMER	2	5	7	8	2
50.30.20.11	FLIGHT OPERATIONS	USER	PROGRAMMER	12	7	12	14	2
50.30.20.12	FLIGHT OPERATIONS	USER	CODER	2	7	12	14	2
50.30.20.21	CHECKOUT & PERFORMANCE MONITOR	USER	PROGRAMMER	8	8	9	12	2
50.30.20.22	CHECKOUT & PERFORMANCE MONITOR	USER	CODER	4	8	9	12	2
50.30.20.41	REPAIR REFURBISHMENT	USER	DESIGNER	2	18	0	18	4
50.30.20.43	REPAIR REFURBISHMENT	LS	DESIGNER	1	18	0	18	4
40.40.21.	RELIABILITY ANALYSIS	USER	SYS ENGR	5	4	5	6	2
50.40.23.	RELIABILITY ANALYSIS	LS	SYS ENGR	1	5	0	5	4
40.40.31.	QC INSPECTION	USER	SYS ENGR	1	13	0	17	4
50.40.32.	QC INSPECTION	LS	SYS ENGR	1	15	0	17	4
50.50.21.	SAFETY ANALYSIS	USER	SYS ENGR	7	3	0	4	4
50.50.23.	SAFETY ANALYSIS	LS	SYS ENGR	3	4	0	4	4
50.50.31.	SAFETY REVIEWS	USER	SYS ENGR	3	8	9	10	2
50.50.33.	SAFETY REVIEWS	LS	SYS ENGR	1	9	0	11	4
50.60.11.	MOCKUPS	USER	DESIGNER	6	9	10	11	3
50.60.12.	MOCKUPS	USER	MECHANIC	4	9	0	11	4
50.80.11.	CONFIGURATION CONTROL	USER	SYS ENGR	10	8	0	17	4
50.80.12.	CONFIGURATION CONTROL	LS	SYS ENGR	6	8	0	17	4
60.10.11.	CABLES AND WIRING	USER	DESIGNER	8	8	9	12	3
60.10.12.	CABLES AND WIRING	USER	MECHANIC	8	8	9	12	3
60.10.21.	STRUCTURES	USER	DESIGNER	10	8	9	12	3
60.10.22.	STRUCTURES	USER	MECHANIC	13	8	9	12	3
60.10.31.	PROTECTIVE ENCLOSURES	USER	DESIGNER	2	9	0	12	4
60.10.32.	PROTECTIVE ENCLOSURES	USER	MECHANIC	1	9	0	12	4

Table 3.1-5. Concept IV Supporting Function Task Estimates (Cont)

WBS NO.	TASK TITLE	CENTER	SKILL CODE	MAN MONTHS	SPREAD OPTION BEGIN	PEAK	END	TYPE
60.20.11.	LEVEL III TEST PLANS	USER	TEST ENGR	30	10	11	12	3
60.20.21.	LEVEL III TEST REPORTS	USER	TEST ENGR	4	13	15	15	2
63.20.11.	LEVEL II TEST PLANS	USER	TEST ENGR	4	11	12	13	3
63.20.12.	LEVEL II TEST PLANS	LS	TEST ENGR	2	11	12	13	3
63.20.21.	LEVEL II TEST REPORTS	USER	TEST ENGR	1	15	0	16	4
63.20.22.	LEVEL II TEST REPORTS	LS	TEST ENGR	2	15	0	16	4
66.20.11.	LEVEL I TEST PLANS	USER	TEST ENGR	5	11	12	13	2
66.20.12.	LEVEL I TEST PLANS	LS	TEST ENGR	4	11	12	13	2
66.20.21.	LEVEL I TEST REPORTS	USER	TEST ENGR	1	17	0	17	4
66.20.22.	LEVEL I TEST REPORTS	LS	TEST ENGR	1	17	0	17	4
66.40.11.	LEVEL I SAFETY REVIEW	USER	SYS ENGR	1	17	0	17	4
66.40.12.	LEVEL I SAFETY REVIEW	LS	SYS ENGR	1	17	0	17	4
70.10.11.	SPECIAL TEST EQUIPMENT	USER	DESIGNER	1	9	0	10	4
70.10.12.	SPECIAL TEST EQUIPMENT	USER	MECHANIC	2	9	0	10	4
70.10.17	SPECIAL TEST EQUIPMENT	USER	TEST ENGR	1	9	0	10	4

Table 3.1-6. Concept V Supporting Function Task Estimates

WBS NO.	TASK TITLE	CENTER	SKILL CODE	MAN MONTHS	SPREAD OPTION			
					BEGIN	PEAK	END	TYPE
30.10.11.	EXPERIMENT REQUIREMENT	USER	OPS ANALYST	8	1	0	2	4
30.10.21.	ORBIT TRAJECTORY ANALYSIS	USER	OPS ANALYST	2	1	0	2	4
30.10.31.	MISSION TIMELINES	USER	OPS ANALYST	1	18	0	18	4
30.10.32.	MISSION TIMELINES	USER	OPS ANALYST	4	2	0	3	4
20.20.11.	OPERATIONS PLANNING	USER	OPS ANALYST	3	1	1	4	3
30.20.12.	OPERATIONS PLANNING	LS	OPS ANALYST	1	2	0	3	4
30.20.13.	OPERATIONS PLANNING	USER	OPS ANALYST	1	18	0	18	4
30.20.21.	RESOURCE ALLOCATION	USER	OPS ANALYST	3	2	2	5	3
30.20.22.	RESOURCE ALLOCATION	LS	OPS ANALYST	1	2	0	3	4
30.20.23.	RESOURCE ALLOCATION	USER	OPS ANALYST	1	18	0	18	4
30.20.31.	CREW TASK TIMELINES	USER	OPS ANALYST	5	3	0	5	4
30.20.41.	CREW SKILLS	USER	OPS ANALYST	2	1	0	1	4
30.30.11.	MISSION PLANS	USER	OPS ANALYST	4	9	0	10	4
30.30.13.	MISSION PLANS	LS	OPS ANALYST	1	9	0	10	4
30.30.21.	MISSION OPERATING INSTRUCTIONS	USER	OPS ANALYST	12	10	11	13	3
30.30.23.	MISSION OPERATING INSTRUCTIONS	LS	OPS ANALYST	1	11	0	11	4
30.30.31.	GROUND SUPPORT PLANS	USER	OPS ANALYST	5	4	0	5	4
30.30.33.	GROUND SUPPORT PLANS	LS	OPS ANALYST	1	5	0	5	4
30.40.11.	EXPERIMENT FLIGHT DATA ANALYSIS	USER	SYS ENGR	2	18	0	18	4
30.40.21.	REPORT PREPARATION	USER	SYS ENGR	1	18	0	18	4
30.40.23.	REPORT PREPARATION	LS	SYS ENGR	1	18	0	18	4
30.50.11.	TRAINING PLANS AND PROCEDURES	USER	OPS ANALYST	3	4	0	4	4
30.50.12.	TRAINING PLANS AND PROCEDURES	LS	OPS ANALYST	1	4	0	4	4
30.50.31.	TRAINING ACTIVITY	USER	SYS ENGR	6	10	0	11	4
40.10.11.	MISSION CONTROL	USER	OPS ANALYST	2	17	0	17	4
40.10.13.	MISSION CONTROL	LS	OPS ANALYST	1	17	0	17	4
40.20.11.	OPERATIONS MONITOR RM	USER	SYS ENGR	4	17	0	17	4
40.20.13.	OPERATIONS MONITOR RM	LS	SYS ENGR	1	17	0	17	4
40.20.21.	DATA TRANSMISSION	USER	MECHANIC	1	17	0	17	4
40.30.11.	GROUND TRUTH SITE	USER	OPS ANALYST	36	3	13	18	3
40.30.12.	GROUND TRUTH SITE	USER	SYS ENGR	36	3	13	18	3
40.30.31.	SPACELAB SUBYSTEMS SUPPORT	USER	SYS ENGR	8	17	0	17	4
50.10.10.11	PERFORMANCE EVALUATION	USER	SYS ENGR	16	1	3	4	3
50.10.10.12	PERFORMANCE EVALUATION	USER	SYS ENGR	7	18	0	18	4
50.10.10.13	PERFORMANCE EVALUATION	LS	SYS ENGR	3	2	3	4	3
50.10.10.14	PERFORMANCE EVALUATION	LS	SYS ENGR	1	18	0	18	4
50.10.10.21	EXPENDABLES LOADS	USER	SYS ENGR	8	8	0	9	4
50.10.10.23	EXPENDABLES LOADS	LS	SYS ENGR	1	8	0	9	4
50.10.10.31	EMI	USER	SYS ENGR	3	2	0	2	4
50.10.10.33	EMI	LS	SYS ENGR	1	2	0	2	4
50.10.21.	FLIGHT AND GROUND REQUIREMENTS	USER	SYS ENGR	12	2	3	5	3
50.10.30.11	TESTS, PARAMETERS & LIMITS	USER	SYS ENGR	15	4	5	5	4
50.10.30.13	TESTS, PARAMETERS & LIMITS	LS	SYS ENGR	2	5	0	5	4
50.10.30.21	CONFIDENCE COST RISK	USER	SYS ENGR	2	5	0	5	4
50.10.41.	GSE FACILITY REQUIREMENTS	USER	SYS ENGR	3	9	0	9	4
50.20.10.11	SYSTEM OPERATING INSTRUCTIONS	USER	DESIGNER	20	7	10	13	3
50.20.10.21	EQUIPMENT SPECIFICATIONS	USER	DESIGNER	20	7	10	13	3
50.20.10.31	CPSE COORDINATION	USER	DESIGNER	5	6	8	12	3
50.20.10.33	CPSE COORDINATION	LS	DESIGNER	2	8	0	9	4
50.20.20.11	LAYOUT AND INSTALLATION	USER	DESIGNER	12	7	9	12	3
50.20.20.12	LAYOUT AND INSTALLATION	LS	DESIGNER	1	8	0	9	4
50.20.20.21	INTERFACE HARDWARE	USER	DESIGNER	13	7	9	12	3
50.20.20.31	TURNAROUND REFURBISHMENT PLAN	USER	DESIGNER	4	8	0	9	4
50.20.30.11	ICDS	USER	DESIGNER	2	6	0	9	4
50.20.30.12	ICDS	LS	DESIGNER	1	6	0	9	4
50.20.41.	COST COMMONALITY ANALYSIS	USER	DESIGNER	2	5	0	5	4
50.20.42.	COST COMMONALITY ANALYSIS	LS	DESIGNER	1	5	0	5	4
50.30.10.11	ORBITER MISSION MODS	USER	PROGRAMMER	2	6	0	7	4
50.30.10.12	ORBITER MISSION MODS	LS	PROGRAMMER	2	6	0	7	4
50.30.10.21	SPACELAB & EXPERIMENT SOFTWARE REQMTS	USER	PROGRAMMER	8	5	7	8	2
50.30.20.11	FLIGHT OPERATIONS	USER	PROGRAMMER	12	7	19	14	2
50.30.20.12	FLIGHT OPERATIONS	USER	CODER	2	7	18	14	2
50.30.20.21	CHECKOUT & PERFORMANCE MONITOR	USER	PROGRAMMER	8	8	9	12	2
50.30.20.22	CHECKOUT & PERFORMANCE MONITOR	USER	CODER	4	8	9	12	2
50.30.20.41	REPAIR REFURBISHMENT	USER	DESIGNER	3	18	0	18	4
50.40.21.	RELIABILITY ANALYSIS	USER	SYS ENGR	6	4	5	6	2
50.40.31.	QC INSPECTION	USER	SYS ENGR	1	13	0	17	4
50.50.21.	SAFETY ANALYSIS	USER	SYS ENGR	7	3	0	4	4
50.50.23.	SAFETY ANALYSIS	LS	SYS ENGR	2	4	0	4	4
50.50.31.	SAFETY REVIEWS	USER	SYS ENGR	3	8	9	10	4
50.50.33.	SAFETY REVIEWS	LS	SYS ENGR	1	9	0	11	4
50.60.11.	MOCKUPS	USER	DESIGNER	6	9	10	11	3
50.60.12.	MOCKUPS	USER	MECHANIC	4	9	0	11	3
50.80.11.	CONFIGURATION CONTROL	USER	SYS ENGR	13	8	0	17	4
50.80.12.	CONFIGURATION CONTROL	LS	SYS ENGR	3	8	0	17	4
60.10.11.	CABLES AND WIRING	USER	DESIGNER	8	8	9	12	3
60.10.12.	CABLES AND WIRING	USER	MECHANIC	8	8	9	12	3
60.10.21.	STRUCTURES	USER	DESIGNER	10	8	9	12	3
60.10.22.	STRUCTURES	USER	MECHANIC	13	8	9	12	3
60.10.31.	PROTECTIVE ENCLOSURES	USER	DESIGNER	2	9	0	12	4
60.10.32.	PROTECTIVE ENCLOSURES	USER	MECHANIC	1	9	0	12	4
60.20.11.	LEVEL III TEST PLANS	USER	TEST ENGR	30	10	11	12	3
60.20.21.	LEVEL III TEST REPORTS	USER	TEST ENGR	4	13	15	15	2
63.20.11.	LEVEL II TEST PLANS	USER	TEST ENGR	5	11	12	13	3
63.20.21.	LEVEL II TEST REPORTS	USER	TEST ENGR	2	15	0	16	4
66.20.11.	LEVEL I TEST PLANS	USER	TEST ENGR	5	11	12	13	2
66.20.12.	LEVEL I TEST PLANS	LS	TEST ENGR	4	11	12	13	2
66.20.21.	LEVEL I TEST REPORTS	USER	TEST ENGR	1	17	0	17	4
66.20.22.	LEVEL I TEST REPORTS	LS	TEST ENGR	1	19	0	17	4
66.40.11.	LEVEL I SAFETY REVIEW	USER	SYS ENGR	1	17	0	17	4
66.40.13.	LEVEL I SAFETY REVIEW	LS	SYS ENGR	1	17	0	17	4
70.10.12.	SPECIAL TEST EQUIPMENT	USER	DESIGNER	1	9	0	10	4
70.10.13.	SPECIAL TEST EQUIPMENT	USER	TEST ENGR	1	9	0	10	4
70.10.14.	SPECIAL TEST EQUIPMENT	USER	MECHANIC	2	9	0	10	4

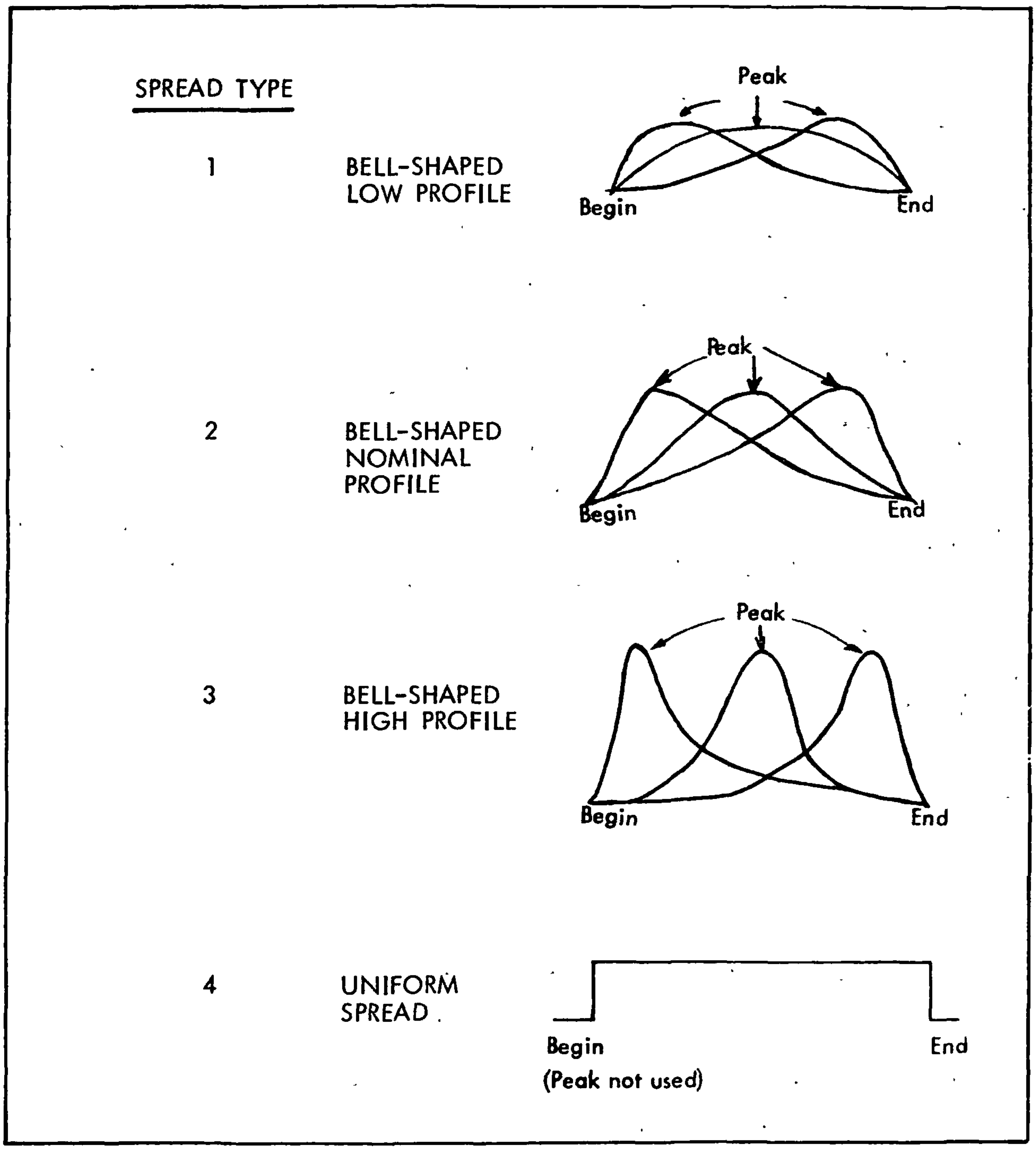


Figure 3.1-6. Manpower Spreading Options

Table 3.1-7. Supporting Function Manpower Requirements (Per-Mission/By Skill Code)

SKILL CODE (MAN-MONTHS) — CONCEPT	I				II				III				IV			V		
CENTER	U	IC	LS	Total	U	IC	LS	Total	U	IC	LS	Total	U	LS	Total	U	LS	Total
OPERATIONS ANALYST	45	53	7	105	45	53	9	107	91	-	9	100	91	9	100	92	7	99
SYSTEMS ENGINEER	59	109	17	185	59	89	38	186	132	18	38	188	140	38	178	154	17	171
DESIGNER	29	83	5	117	29	81	13	123	58	54	13	125	106	13	119	110	5	115
PROGRAMMER	6	26	2	34	6	26	4	36	28	-	4	32	28	4	32	30	2	32
CODER	-	6	-	6	-	6	-	6	6	-	-	6	6	-	6	6	-	6
TEST ENGINEER	6	48	5	59	6	46	9	61	46	3	9	58	46	9	55	48	5	53
MECHANIC	1	29	-	30	1	29	-	30	7	22	-	29	29	0	29	27	-	27
TOTALS	146	354	36	536	146	330	73	549	368	97	73	538	446	73	519	467	36	503

NOTE: ALL FIGURES ARE MAN-MONTHS

The steady-state and part-time personnel requirements for supporting function activities for each center for each of the five complete Spacelab processing concepts are presented in Table 3.1-8. This staffing arrangement could support a flight rate of two per year. The test engineer skill code was only used for such tasks as test plans, procedures and reports. Composite test engineer requirements that include test and operations activities are derived in subsequent paragraphs.

Table 3.1-8. Supporting Function Personnel Requirements (Two Flights Per Year)

SKILL CODE / CONCEPT	I			II			III			IV		V	
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	LS	U	LS
OPERATIONS ANALYST	8	9	1	8	9	2	15	0	2	15	2	15	1
SYSTEMS ENGINEER	9	18	3	10	15	6	22	3	6	23	6	26	3
DESIGNER	5	(6) 11	(2) 0	5	(6) 10	(2) 1	(4) 8	(6) 6	(2) 1	(12) 12	(2) 1	(12) 13	(2) 0
PROGRAMMER	(2) 0	(3) 3	(1) 0	(2) 0	(3) 3	(1) 0	(3) 3	0	(1) 0	(3) 3	(1) 0	(3) 3	(1) 0
CODER	0	1	0	0	1	0	1	0	0	1	0	1	0
TEST ENGINEER	(2) 0	(8) 4	(2) 0	(2) 0	(7) 4	(3) 0	(7) 4	(1) 0	(3) 0	(7) 4	(3) 0	(8) 4	(2) 0
MECHANIC	0	(3) 3	0	0	(3) 3	0	1	(6) 1	0	(6) 2	0	(6) 2	0
TOTALS	(4) 22	(20) 49	(5) 4	(4) 23	(19) 45	(6) 9	(14) 54	(13) 10	(6) 9	(28) 60	(6) 9	(29) 64	(5) 4
	(29) 75			(29) 77			(33) 73			(34) 69		(34) 68	
NOTE: ALL FIGURES ARE NUMBER OF PERSONS.													

LEGEND: (XX) PART TIME
XX FULL TIME

Pallet-Only Configuration

The supporting function tasks, manpower estimating techniques and optimization approach for the pallet-only ATL configuration are the same as for the complete Spacelab. The initial pallet-only configuration used in the study probably would have resulted in manpower requirements significantly different than those for a complete Spacelab. The initial configuration did not include a support systems igloo and it was assumed that there would be no multi-mission support equipment installed in the Orbiter payload specialist or mission specialist stations (PSS/MSS). Requirements definition, design, fabrication, and interface control tasks would have been significantly greater.

An interim pallet-only configuration was derived for study purposes. The configuration consisted of a non-habitable short module (to house support system equipment and experiment support equipment) in the aft section of the cargo bay and four pallet sections between the short module and the Orbiter forward bulkhead. The configuration resulted in experiment and "Spacelab" integration (Levels III and II) tasks for the pallet-only configuration being very similar to the comparable complete Spacelab tasks. Orbiter integration (Level I) was still significantly different for the two configurations.

The definition of the igloo for housing support systems and identification of multi-mission support equipment to be installed in the PSS and/or MSS for operation and control of the support systems and experiments eliminated significant differences in the supporting function tasks for the two ATL configurations.[1] In essence, the integration effort associated with the use of the centralized controls and displays in the support module of the Spacelab is applied to comparable tasks to define and implement the control and display functions that will be included in the PSS/MSS for the pallet-only configuration.

A summary of the comparison of the effort associated with each supporting function task for both ATL configurations is presented in Table 3.1-9. The comments are based upon the comparison of the pallet-only effort to the complete Spacelab effort.

[1]The similarity is applicable to the integration activities of an ATL payload. It is anticipated that experiment development and hardware configuration will be significantly different for the two configurations. With a complete Spacelab, dedicated controls and displays are feasible. The physical constraints of the PSS and MSS impose additional remote control/automation requirements on the experiment hardware for the pallet-only configuration.

Table 3.1-9. Comparison of Tasks for Alternate ATL Configurations

WBS Number	Task Title	Man-Months Spacelab	Man-Months Pallet Only	Comments
30-20-30	Crew Timelines	5	3	Less crewmen, more automated functions
50-10-20-10	Flight and Ground Requirements	12	14	Additional planning for handling contingency/target of opportunity situations because of inherent limitations of remote/automated experiment operations.
50-10-30-10	Test Parameters and Limits	18	10	Reflects significant reduction in manual operations and thus manual test operations.
50-20-40-10	Cost/Commonality Analysis	3	2	Minor reductions attributed to elimination of some functions that were duplicated with Spacelab (e.g., support module/MSS caution and warning).
50-30-10-20	Experiment Software Requirements	8	16	Development of automated/shared operations because of limited control and display space at PSS/MSS.
50-30-20-10	Flight Operations Software	14	20	Automated scheduling and intermixing of experiment operations.
50-30-20-20	Checkout and Performance Monitor Software	12	16	Simultaneous experiment operations with shared displays requires delta software.
50-80-10	Configuration Control	18	12	Less end item hardware
60-20-10	Test Plans and Procedures (Level III)	36	30	Less manual--more automatic operations, therefore simplified testing.
63-20-10	Test Plans and Procedures (Level II)	5	3	Man-machine interface verified at Level III integration.
66-20-10	Test Plans and Procedures (Level I)	9	15	Complexity of Orbiter/PSS-payload interfaces.
	Totals	140	141	

The minor differences between tasks did not warrant a complete reoptimization of program requirements. The evolution of the pallet-only configuration to its present definition, coupled with the identification of the baseline design of the support module-experiment module (Level III integration includes experiment installation and checkout on racks and pallets only) has resulted in the three pallet-only processing options being almost identical to three of the complete Spacelab processing options (Concepts II, III and IV). The supporting function manpower estimates for the comparable processing concepts for the two configurations are indicated in Table 3.1-10. The similarities between tasks, personnel requirements and scheduling for the two configurations will permit intermixing of complete Spacelabs and pallet-only payloads in the continuing ATL program.

Table 3.1-10. Supporting Function Manpower Estimates

Configuration		Manpower Estimates (Man-Months Per Mission)			
Pallet-Only	Complete Spacelab	User	Integration Center	Launch Site	Total
VI	III	368	97	73	538
VII	II	146	337	73	549
VIII	IV	446	-	73	519

TEST AND OPERATIONS

Personnel estimates for the test and operations activities for the candidate processing concepts are limited to the engineers and technicians actually conducting the work. Provisions were made in supporting function estimates for systems support during the tests. In addition, the PI/payload specialists and discipline specialists are part of the checkout team. These personnel are actually part of the sustaining organization (see Section 4.0, Volume III). The optimization studies presented in Volume II indicated that utilization of the payload specialists and discipline specialists as checkout team members was the most efficient technique for crew training, PI involvement, and mission simulation.

Task Estimates

Each task of the detailed flow diagrams, developed in Section 4.2 of Volume II, was analyzed to determine the number of personnel (by skill code) that was required. Except for Functional Block 1.0, Experiment Shipment, the manpower requirements to accomplish the basic tasks are independent of concept. The applicability of the T&O functional block, the center that conducts the test and/or operation, and the support from other centers does vary with concept. Table 3.1-11 tabulates the man-months of effort required for the accomplishment of each basic T&O task and also indicates the center performing the function. Transportation functional blocks are subdivided to differentiate between the efforts of the shipping operation at one center and the receiving operation at a second center.

The variation in the effort for pre-mission shipment of experiments (Functional Block 1.0) occurs because in Concepts I and II inter-center (user-integration center) transfer is required; whereas, in Concepts III, IV, and V only intra-center transfer is required at the user's site. Post-mission experiment shipment (Functional Block 20.0) was estimated to be the same for all concepts. Disposition of experiment equipment may be shipment to the user center and/or to equipment manufacturer for refurbishment/modification. Thus,

Table 3.1-11. Manpower Requirements for Basic T&O Tasks
(Man-Months)

BLOCK NO.	MAJOR FUNCTIONAL ACTIVITY	SKILL CODE		CONCEPT APPLICABILITY				
		ENGR	TECH	I	II	III	IV	V
1.0	EXPERIMENT SHIPMENT		1.8/0.6	U	U	U	U	U
2.0	EXPERIMENT INSTALLATION	3.1	12.9	IC	IC	U	U	U
3.0	CONNECT SM INTERFACE SIM	0.7	2.6	IC	IC	U	U	U
4.0	EXPERIMENT INTEGRATION	5.4	15.8	IC	IC	U	U	U
5.0	GSE DISCONNECT	0.1	0.3	IC	IC	U	U	U
6.0	RACKS/PALLET SHIPMENT							
	SHIPPING	0.2	1.2		IC	U	U	
	RECEIVING	0.1	0.9		LS	LS	LS	
7.0	MATE RACKS/PALLET-EM/SM SHELLS	0.2	0.9	IC	LS	LS	LS	U
8.0	SPACELAB INTEGRATION	1.6	5.7	IC	LS	LS	LS	U
9.0	SPACELAB SHIPMENT TO LS	0.2	1.1	IC				U
10.0	SPACELAB OFF-LOAD	0.2	0.8	LS				LS
11.0	ORBITER CARGO INTEGRATION	0.5	2.1	LS	LS	LS	LS	LS
12.0	LAUNCH OPERATIONS	0.6	1.9	LS	LS	LS	LS	LS
13.0	MISSION OPERATIONS (REF)	-	-	-	-	-	-	-
14.0	POSTFLIGHT OPERATIONS	0.1	0.8	LS	LS	LS	LS	LS
15.0	SPACELAB MOVE TO MSOB	0.1	0.8		LS	LS	LS	
16.0	SPACELAB SHIPMENT FROM LS							
	SHIPPING	0.1	0.6	LS				LS
	RECEIVING	0.1	0.8	IC				U
17.0	DEMATE EM/SM SHELLS	0.1	0.4	IC	LS	LS	LS	U
18.0	RACKS/PALLET SHIPMENT							
	SHIPPING	0.2	1.3		LS	LS	LS	
	RECEIVING	0.1	0.9		IC	IC	U	
19.0	REFURBISH RACKS/PALLET	0.4	2.5	IC	IC	IC	U	U
20.0	EXPERIMENT SHIPMENT	0.3	1.7	IC	IC	IC	U	U
21.0	REFURBISH SUPPORT SYS & EM/SM SHELLS	0.4	4.1	IC	LS	LS	LS	U
22.0	POST REFURB RACKS/PALLET SHIPMENT							
	SHIPPING	0.2	1.4			IC		
	RECEIVING	0.1	0.9			U		

in Concepts IV and V, allowances were made for equipment shipment from the user center's integration facility to both on-site principal investigators and equipment vendors. In Concepts I, II and III, postflight shipment of experiment equipment from the integration center can be either to the user center or directly to the equipment vendor.

The PI/payload specialists, discipline specialists and certain members of the supporting function staff accompany the flight hardware throughout the processing cycle regardless of the site location of the checkout activity. It is believed that, for maximum efficiency of operations, certain test personnel should also accompany the flight hardware when transfer of equipment is required by the concept. For example, in Concept III the rack and pallet are refurbished at the integration center and then transferred to the user center for Level III integration. It is recommended that an electrical and mechanical test engineer from the integration center be stationed at the user center during Level III integration. Similarly, upon shipment of the integrated racks and pallet to the launch site for Levels II and I integration, it is recommended that an electrical and mechanical test engineer from the user center be a member of the test team during launch site operations. Table 3.1-12 summarizes the off-site support requirements for the five processing concepts. Because of the idiosyncracies of the GSE equipment, facilities and operations at each center in the processing cycle, it is recommended that only test engineers be assigned to off-site support; only on-site (resident) technician help should be utilized.

Table 3.1-12. Off-Site T&O Manpower Requirements
(Man-Months)

BLOCK NO.	MAJOR FUNCTIONAL ACTIVITY	TEST ENGINEER	CONCEPT APPLICABILITY				
			I	II	III	IV	V
1.0	EXPERIMENT SHIPMENT						
2.0	EXPERIMENT INSTALLATION	2.0			IC		
3.0	CONNECT SM INTERFACE SIMULATOR	0.4			IC		
4.0	EXPERIMENT INTEGRATION	3.6			IC		
5.0	GSE DISCONNECT	0.1			IC		
6.0	RACKS/PALLET SHIPMENT	0.7			U		
7.0	MATE RACKS/PALLET-EM/SM SHELLS	0.3		IC	U	U	
8.0	SPACELAB INTEGRATION	1.0		IC	U	U	
9.0	SPACELAB SHIPMENT TO LS						
10.0	SPACELAB OFF-LOAD						
11.0	ORBITER CARGO INTEGRATION	0.7*/0.5	IC	IC	U	U	U
12.0	LAUNCH OPERATIONS	0.7*/0.4	IC	IC	U	U	U
13.0	MISSION OPERATIONS (REF)						
14.0	POSTFLIGHT OPERATIONS						
15.0	SPACELAB MOVE TO MSOB						
16.0	SPACELAB SHIPMENT FROM LS						
17.0	DEMATE EM/SM SHELLS						
18.0	RACKS/PALLET SHIPMENT						
19.0	REFURBISH RACKS/PALLET						
20.0	EXPERIMENT SHIPMENT						
21.0	REFURBISH SUPPORT SYS AND EM/SM SHELLS						
22.0	POST-REFURB RACKS/PALLET SHIPMENT						

*CONCEPTS I AND V ONLY.

The increase in off-site test support for Concepts I and V reflects the addition of a control and display oriented test engineer for coordination of the installation and integration of the support module into the Orbiter. In Concepts II, III and IV, when the support module stays at the launch site, launch site personnel will perform all the control and display integration functions of the support module.

Optimization of Personnel

The System Cost Model (Appendix E) was used to combine the per-task manpower estimates and the checkout schedule of each processing concept for each skill code. The actual man-months of effort required per calendar month for each concept, including both on-site and off-site support, are plotted in Figures 3.1-7 through 3.1-9.

Concepts I and V require the same manpower; only the cognizant site changes for non-launch site activities. Concepts II and IV also have comparable manpower requirements but varying cognizance. Concept III (Figure 3.1-9) requirements are unique. The discrete phasing of the flight hardware through three centers is apparent from the technician requirements. Launch site support requirements are identifical for Concepts I and V and II, III and IV.

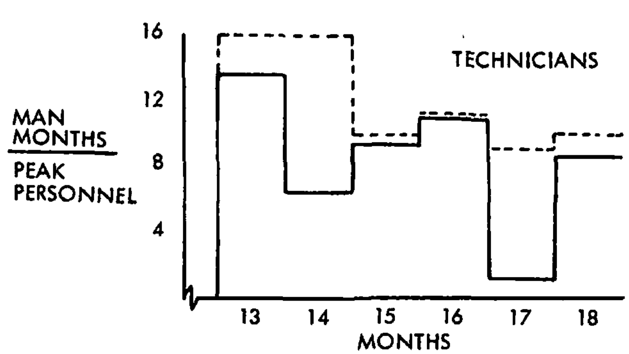
Actual personnel requirements are not the equivalent of the man-months of effort. In order to minimize the processing time, the maximum number of personnel that could be effectively employed in a test or operation were assigned and are indicated in the figures. In a given calendar month, one task may require 16 people and a second task performed in the same calendar month may require only 10 people. It is impractical to assign and reassign personnel on such a short-term basis. The peak number of personnel required at any one time is also shown on the figures. However, staffing the T&O activity with the maximum requirement would be extremely inefficient. Therefore, a "weighted" average plus part-time staff approach was adopted.

In all five complete Spacelab processing concepts, a peak load occurs during the first 2 to 3 months of the test and operation activities. The latter three months exhibit a relatively constant personnel requirement. For those concepts where the skill code at a site is required for the six-month duration, a weighted average approximately equal to the maximum number of personnel required during the last three months of the processing cycle was selected as the steady-state full-time staff. In addition, a part-time staff was assumed for the first three months of the effort to fulfill the demand of the peak period. In all the processing concepts, the launch site support team is on a part-time basis. That is, the launch site is assigned to alternately support an ATL Spacelab and one other Spacelab every three months in Concepts II, III and IV. In Concepts I and V, the launch site team could support three Spacelabs every six months in two-month increments.

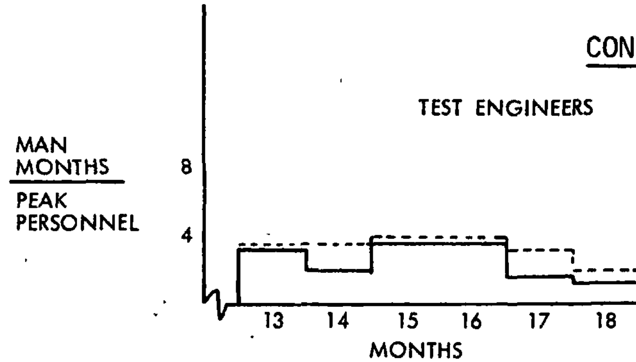
Makeup and assignment of the part-time support team at the integration center would be on the same basis as its launch site team. This part-time team would be sequentially scheduled to support multiple Spacelab users.

CONCEPT I: INTEGRATION CENTER

CONCEPT V: USER

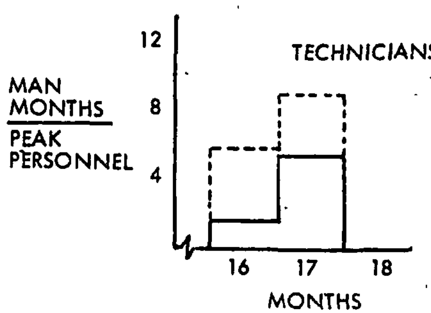


MAN MONTHS	12.5	6.2	9.4	11.0	1.0	8.7
PEAK REQMT	16	16	10	11	9	10
STAFF	9	9	9	9	9	9
	5	5	5			

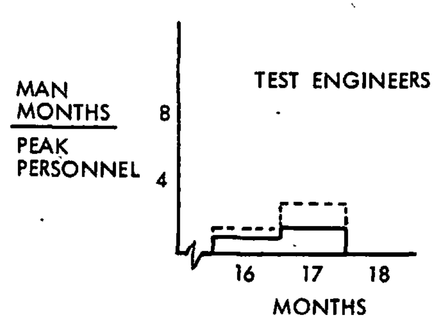


MAN MONTHS	3.0	1.9	3.2	3.2	1.4	1.2
PEAK REQMT	3	3	4	4	3	2
STAFF	3	3	3	3	3	3

CONCEPTS I & V: LAUNCH SITE



MAN MONTHS	0.8	5.4
PEAK REQMT	6	9
STAFF	8	8



MAN MONTHS	0.2	1.3
PEAK REQMT	1	3
STAFF	2	2

LEGEND:
—— MAN MONTHS
- - - - PEAK PERSONNEL

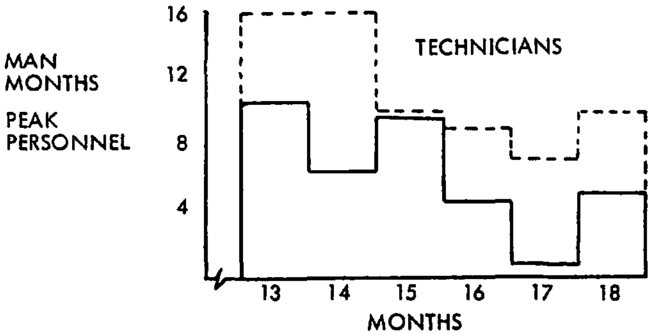
Figure 3.1-7. Concepts I and V T&O Staffing Requirements

CONCEPT II:

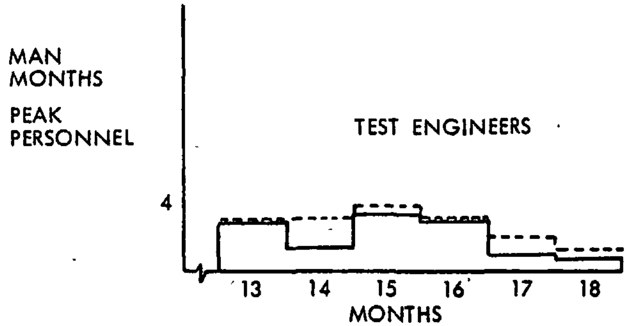
INTEGRATION CENTER

CONCEPT IV:

USER



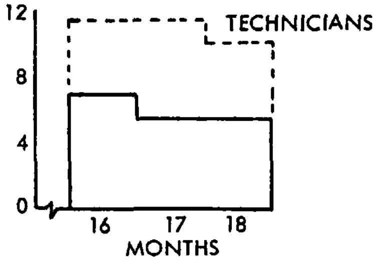
MAN MONTHS	12.5	6.2	9.4	4.4	0.3	5.1
PEAK REQMT	16	16	10	9	7	10
STAFF	8	8	8	8	8	8
	5	5	5			



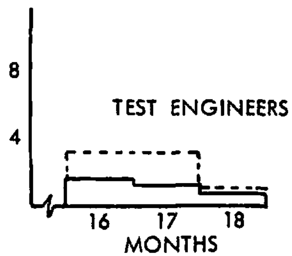
MAN MONTHS	3.0	1.5	3.2	2.7	0.9	0.8
PEAK REQMT	3	3	4	3	2	1
STAFF	2	2	2	2	2	2
	1	1	1			

CONCEPTS II & IV:

LAUNCH SITE



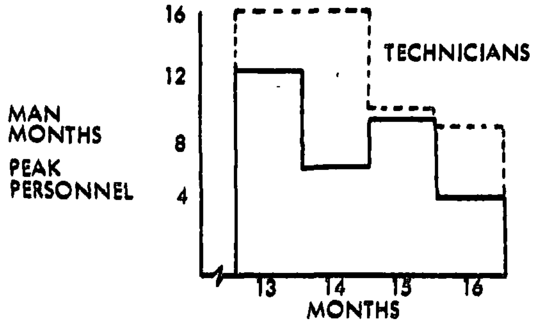
MAN MONTHS	7.3	5.8	5.8
PEAK REQMT	11	11	10
STAFF	11	11	11



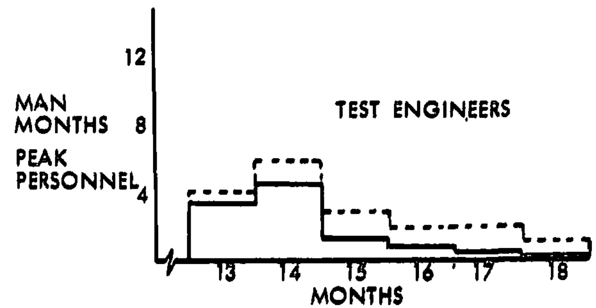
MAN MONTHS	1.8	1.4	0.7
PEAK REQMT	3	3	1
STAFF	2	2	2

LEGEND:
—— MAN MONTHS
---- PEAK PERSONNEL

Figure 3.1-8. Concepts II and IV T&O Staffing Requirements

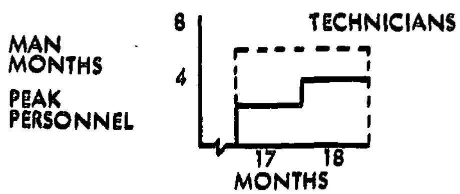


MAN MONTHS	12.5	6.2	9.4	4.9
PEAK REQMT	16	16	10	9
STAFF	12	12	12	12

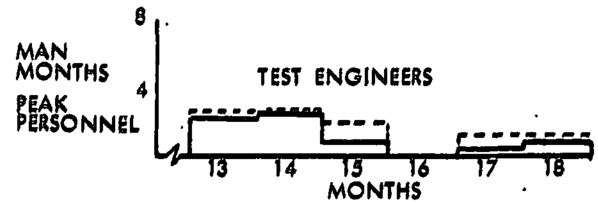


MAN MONTHS	3.8	4.9	1.9	1.8	0.4	0.1
PEAK REQMT	4	5	3	2	2	1
STAFF	2	2	2	2	2	2
	2	2	2			

USER

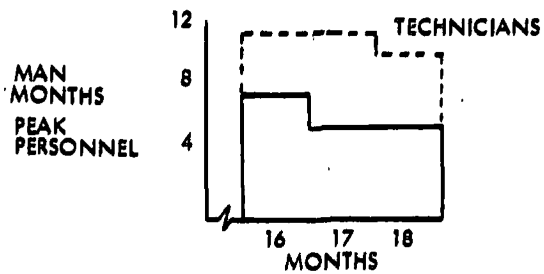


MAN MONTHS	2.5	4
PEAK REQMTS	6	6
STAFF	6	6

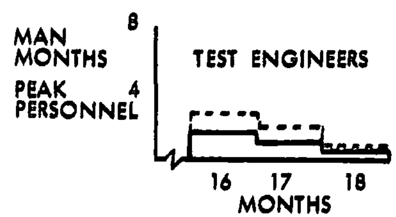


MAN MONTHS	2.4	3.0	0.6	0.1	0.4	0.6
PEAK REQMT	3	3	2	1	1	1
STAFF	1	1	1	1	1	1
	2	2	2			

INTEGRATION CENTER



MAN MONTHS	7.3	5.8	5.8
PEAK REQMT	11	11	10
	11	11	11



MAN MONTHS	1.8	1.4	0.7
PEAK REQMT	3	2	1
STAFF	2	2	2

LAUNCH SITE

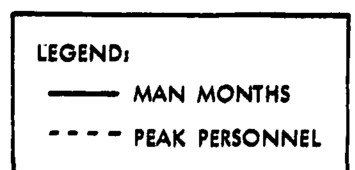


Figure 3.1-9. Concept III T&O Staffing Requirements

Part-time support at the user center in Concepts III, IV and V could be achieved by utilizing PI experiment-development personnel. This approach is highly desirable because the part-time support is required during experiment installation and checkout. Direct involvement of these personnel would provide the benefit of experience gained during equipment development to the integration and checkout activities.

Table 3.1-13 presents a comparison of task effort, maximum headcount, and weighted average man-month requirements. The weighted average approach is a significant improvement from the maximum headcount approach, but is still much greater than actual task estimates. The so-called slack time for the technicians could be utilized for maintenance of Spacelab-unique GSE and facilities. The test engineer requirements for T&O activities are combined with supporting function requirements in a subsequent section to minimize the slack time of this skill code.

Table 3.1-13. T&O Manpower Requirements Summary (Man-Months)

ESTIMATING TECHNIQUE	CONCEPT				
	I	II	III	IV	V
TASK	72.2	72.8	81.7	72.8	72.2
MAXIMUM HEADCOUNT	144	162	163	162	144
WEIGHTED AVERAGE	107	116	128	116	107

Pallet-Only Configuration

The techniques for developing the personnel requirements for the T&O activities associated with the processing of the pallet-only ATL configurations were the same as those for the complete Spacelab. Table 3.1-14 presents the man-month estimates by skill code for each checkout function, and identifies the center that will perform the activity. The off-site test engineering support requirements are identified in Table 3.1-15. As in the case of the T&O activities for the complete Spacelab, the manpower requirements to perform the basic tasks for the pallet-only configuration are the same for all three concepts. Only the cognizant center and the support requirements vary. The results of combining the task estimates with the time-sequenced test and operations for the three pallet-only processing concepts are plotted in Figures 3.1-10 and 3.1-11. The maximum headcount required by a task in each calendar month is superimposed on these figures. Utilizing the weighted average and part-time crew approach, the personnel requirements at each center for each processing concept are also identified in these figures.

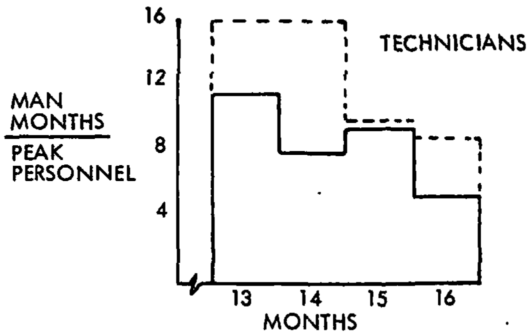
Table 3.1-14. Pallet-Only T&O Task Requirements (Man-Months)

BLOCK NO.	MAJOR FUNCTIONAL ACTIVITY	SKILL CODE		CONCEPT APPLICABILITY		
		ENGR	TECH	VI	VII	VIII
1.0	EXPERIMENT SHIPMENT		2.1*/.6	U	U	U
2.0	EXPERIMENT INSTALLATION	3.2	13.8	U	IC	U
3.0	CONNECT & CHECK OUT IGLOO/ORBITER SIM SET	0.9	2.6	U	IC	U
4.0	EXPERIMENT INTEGRATION	5.4	16.2	U	IC	U
5.0	GSE DISCONNECT	0.3	0.8	U	IC	U
6.0	PALLET/IGLOO SHIPMENT	0.2	1.1	U	IC	U
7.0	PALLET/IGLOO & PSS EQUIPMENT ARRIVAL AT LS	0.1	0.8	LS	LS	LS
8.0	MATE PALLET AND IGLOO (SUPPORT SYSTEM)	0.1	0.8	LS	LS	LS
9.0	SPACELAB INTEGRATION	1.5	5.6	LS	LS	LS
10.0	ORBITER CARGO INTEGRATION	0.4	1.9	LS	LS	LS
11.0	LAUNCH OPERATIONS	0.6	1.9	LS	LS	LS
12.0	MISSION OPERATIONS (REF)	-	-	-	-	-
13.0	POSTFLIGHT OPERATIONS	0.1	0.8	LS	LS	LS
14.0	REFURBISH SUPPORT SYSTEM IGLOO	0.4	3.4	LS	LS	LS
15.0	PALLET/IGLOO SHIPMENT					
	SHIPPING	0.1	0.8	LS	LS	LS
	RECEIVING	0.1	0.9	IC	IC	U
16.0	REMOVE EXPERIMENTS/EQUIPMENT FROM IGLOO	0.3	1.5	IC	IC	U
17.0	EXPERIMENT SHIPMENT	0.1	0.8	IC	IC	U
18.0	REFURBISH/RECONFIGURE PALLET AND IGLOOS	0.2	0.9	IC	IC	U
19.0	POST-REFURB PALLET/IGLOO SHIPMENT					
	SHIPPING	0.2	1.2	IC		
	RECEIVING	0.1	0.5	U		
* CONCEPT VII ONLY						

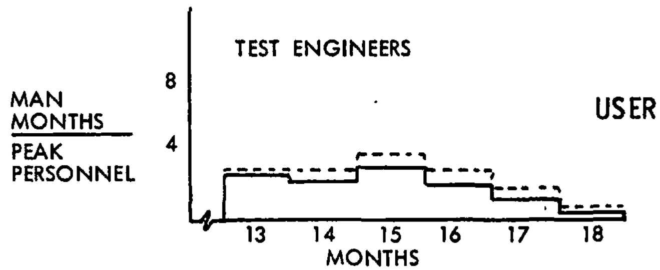
Table 3.1-15. Pallet-Only Off-Site Support Requirements (Man-Months)

BLOCK NO.	MAJOR FUNCTIONAL ACTIVITY	TEST ENGINEERS	CONCEPT APPLICABILITY		
			VI	VII	VIII
1.0	EXPERIMENT SHIPMENT				
2.0	EXPERIMENT INSTALLATION	2.1	IC		
3.0	CONNECT & CHECK OUT IGLOO/ORBITER SIM SET	0.6	IC		
4.0	EXPERIMENT INTEGRATION	3.6	IC		
5.0	GSE DISCONNECT	0.3	IC		
6.0	PALLET/IGLOO SHIPMENT				
7.0	PALLET/IGLOO & PSS EQUIP ARRIVAL AT LS	0.2	U	IC	U
8.0	MATE PALLET & IGLOO (SUPPORT SYSTEM)	0.3	U	IC	U
9.0	SPACELAB INTEGRATION	1.0	U	IC	U
10.0	ORBITER CARGO INTEGRATION	0.4	U	IC	U
11.0	LAUNCH OPERATIONS	0.4	U	IC	U
12.0	MISSION OPERATIONS (REF)				
13.0	POSTFLIGHT OPERATIONS				
14.0	REFURBISH SUPPORT SYSTEM IGLOO				
15.0	PALLET/IGLOO SHIPMENT				
16.0	REMOVE EXPERIMENTS/EQUIPMENT FROM IGLOO				
17.0	EXPERIMENT SHIPMENT				
18.0	REFURBISH/RECONFIGURE PALLET AND IGLOO				
19.0	POST-REFURB PALLET/IGLOO SHIPMENT				

USER

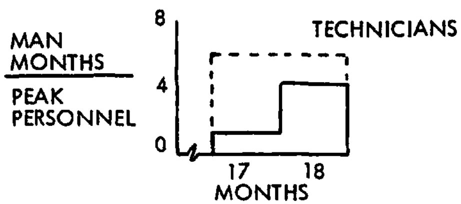


MAN MONTHS	11.6	8.1	9.6	5.2
PEAK REQMT	16	16	10	9
STAFF	12	12	12	12

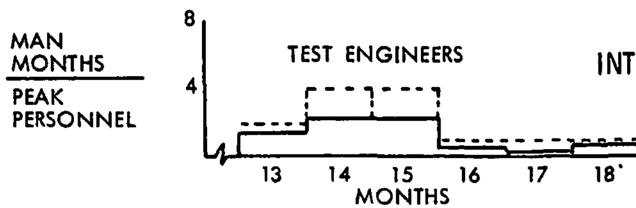


MAN MONTHS	2.7	2.5	3.2	2.3	1.6	0.1
PEAK REQMT	3	3	4	3	2	1
STAFF	2	2	2	2	2	2
	1	1	1			

INTEGRATION CENTER

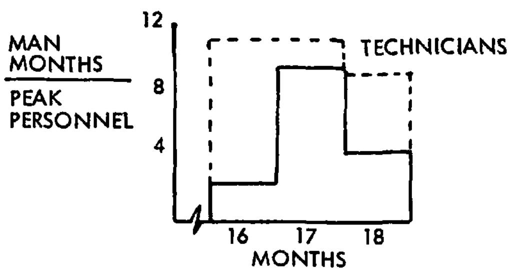


MAN MONTHS	1.2	4.1
PEAK REQMT	6	6
STAFF	6	6

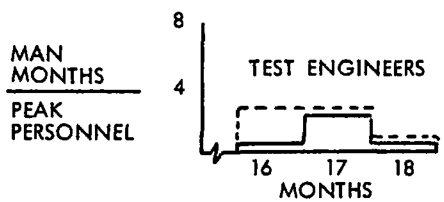


MAN MONTHS	1.4	2.1	2.1	0.9	0.1	0.9
PEAK REQMT	2	3	3	1	1	1
STAFF	1	1	1	1	1	1
	2	2	2			

LAUNCH SITE



MAN MONTHS	2.5	9.3	4.2
PEAK REQMT	11	11	9
STAFF	11	11	11

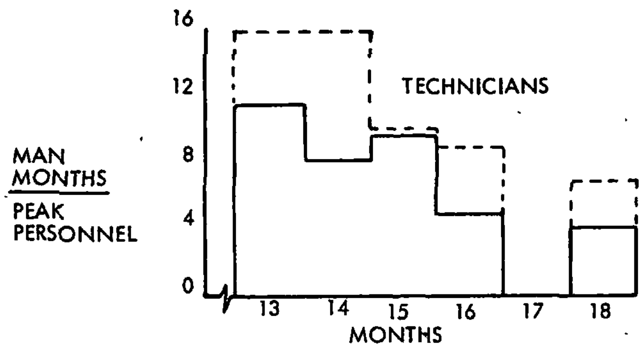


MAN MONTHS	0.5	2.3	0.5
PEAK REQMT	3	3	1
STAFF	2	2	2

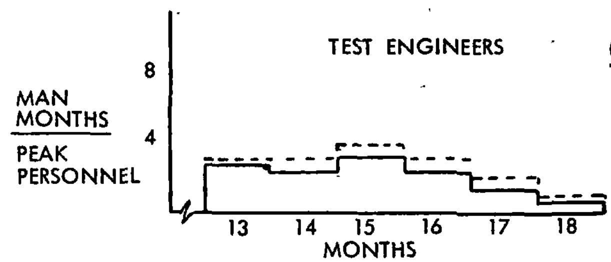
LEGEND
—— MAN MONTHS
- - - - PEAK PERSONNEL

Figure 3.1-10. Concept VI T&O Staffing Requirements

CONCEPT VII: INTEGRATION CENTER
CONCEPT VIII: USER

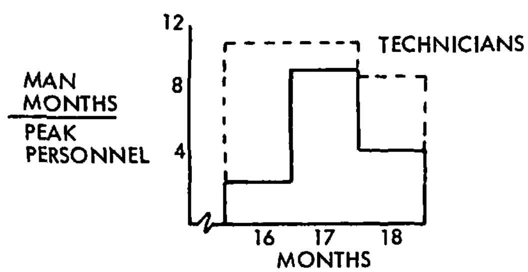


MAN MONTHS	11.6	8.1	9.6	5.2	-	4.1
PEAK REQMT	16	16	10	9	-	7
STAFF	8	8	8	8	8	8
	5	5	5			

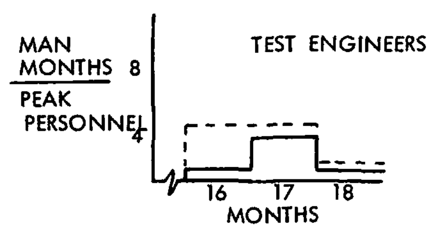


MAN MONTHS	2.7	2.5	3.2	2.2	1.7	0.7
PEAK REQMT	3	3	4	3	2	1
STAFF	2	2	2	2	2	2
	1	1	1			

CONCEPTS VII & VIII: LAUNCH SITE



MAN MONTHS	2.5	9.3	4.2
PEAK REQMT	11	11	9
STAFF	11	11	11



MAN MONTHS	0.5	2.3	0.5
PEAK REQMT	3	3	1
STAFF	2	2	2

LEGEND:
—— MAN MONTHS
- - - - PEAK PERSONNEL

Figure 3.1-11. Concepts VII and VIII T&O Staffing Requirements

Table 3.1-16 summarizes the T&O staffing for the pallet-only processing concepts. Comparison of Tables 3.1-16 and 3.1-13 indicates the staffing of Concepts VI, VII and VIII are almost identical to Concepts III, II and IV, respectively. Thus, as in the case of the supporting functions, there are no significant differences in personnel requirements for the two configurations. Intermixing of configurations can be readily accomplished.

Table 3.1-16. Pallet-Only T&O Manpower Requirements Summary (Man-Months)

ESTIMATING TECHNIQUE	CONCEPT VI	CONCEPT VII	CONCEPT VIII
TASK	79.0	70.9	70.9
MAXIMUM HEADCOUNT	160	162	162
WEIGHTED AVERAGE	123	117	117

COMPOSITE REQUIREMENTS

One additional integration/optimization of personnel requirements was performed. Test engineers were required to perform supporting function tasks and also test and operations tasks. Combining these two requirements would eliminate the potential of periodic slack periods in the T&O activities and also permit a reduction in the composite test engineer requirements. Table 3.1-17 summarizes the requirements of each of the activities and the results of integrating the two activities. This integration of personnel requirements will permit the same group of test engineers to prepare the test plans, conduct the tests, prepare the reports, and then provide positive feedback into the T&O activities of the next payload. This continuity of test engineer activities should increase the efficiency in the processing of flight hardware and also provide a close interrelationship between supporting functions and T&O activities.

A summary of the mission-unique personnel requirements for support functions and T&O activities for each center, for each concept, by skill code, is presented in Table 3.1-18. Both full-time and part-time personnel requirements are indicated. The complement of full-time personnel will support the integration and checkout of two ATL Spacelabs per year, based upon the recommended approach of three ATL Spacelabs in process at any given time. The part-time personnel identified in the table would be utilized approximately half-time in the support of the processing of two Spacelab payloads.

Based upon the staffing requirements, a compilation of the per-mission man-months of effort for each major WBS category is presented in Tables 3.1-19 through 3.1-22. As stated previously, the assumption was made that the accomplishment of the basic task--whether it be a supporting function or a test or operation--requires the same man-months of effort regardless of where or who performs the function. For a success-oriented operational program, such as used in these estimates, the assumption is considered valid. The differences in task estimates between concepts is a direct result of the delta coordination, review, approval, documentation, etc., that would be required when multiple centers are involved in the performance of a task.

Table 3.1-17. Integrated Test Engineer Requirements

ACTIVITY \ CONCEPT	I			II & VII			III & VI			IV & VIII		V		
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	LS	U	LS	
SUPPORT	(2) -	(8) 4	(2) -	(2) -	(7) 4	(3) -	(7) 4	(1) -	(3) -	(7) 4	(3) -	(8) 4	(2) -	NO. OF PERSONNEL
TEST & OPERATIONS	- -	- 3	(2) -	- -	(1) 2	(2) -	(2) 2	(2) 1	(2) -	(1) 2	(2) -	- 3	(2) -	NO. OF PERSONNEL
MISSION-UNIQUE (COMPOSITE)	(2) -	- 9	(3) -	(2) -	- 8	(3) 1	- 9	(3) -	(3) 1	- 9	(3) 1	- 10	(3) -	NO. OF PERSONNEL
MISSION-UNIQUE (NON-INTEGRATED)	84			81			93			78		78		MAN-MONTHS
MISSION-UNIQUE (INTEGRATED)	69			69			78			69		69		MAN-MONTHS

Table 3.1-18. Mission-Unique Personnel Requirements (Two Flights Per Year)

SKILL CODE \ CONCEPT	I			II & VII			III & VI			IV & VIII		V	
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	LS	U	LS
OPERATIONS ANAL.	8	9	1	8	9	2	15	0	2	15	2	15	1
SYSTEMS ENGINEER	9	18	3	10	15	6	22	3	6	23	6	26	3
DESIGNER	5	(6) 11	(2) 0	5	(6) 10	(2) 1	(4) 8	(6) 6	(2) 1	(12) 12	(2) 1	(12) 13	(2) 0
PROGRAMMER	(2) 0	(3) 3	(1) 0	(2) 0	(3) 3	(1) 0	(3) 3	0	(1) 0	(3) 3	(1) 0	(3) 3	(1) 0
CODER	0	1	0	0	1	0	1	0	0	1	0	1	0
TEST ENGINEER	(2) 0	9	(3) 0	(2) 0	8	(3) 1	9	(3) 0	(3) 1	9	(3) 1	10	(3) 0
TEST TECHNICIAN	0	(5) 9	(8) 0	0	(5) 8	(11) 0	(12) 0	(6) 0	(11) 0	(5) 8	(11) 0	(5) 9	(8) 0
MECHANIC	0	(3) 3	0	0	(3) 3	0	1	(6) 1	0	(6) 2	0	(6) 2	0
TOTALS	(4) 22	(17) 63	(14) 4	(4) 23	(17) 57	(17) 10	(19) 59	(21) 10	(17) 10	(26) 73	(17) 10	(26) 79	(14) 4
	(35) 89			(38) 90			(57) 79			(43) 83		(40) 83	

LEGEND:
(XX) PART TIME
XX FULL TIME

Table 3.1-19. Per-Mission Manpower Requirements for Mission-Unique Tasks (Man-Months)

WBS Task \ Concept	I	II & VII	III & VI	IV & VIII	V
30-00 Mission Analysis	78	79	72	72	70
40-00 Mission Operations	93	94	92	92	89
50-00 Systems Engineering	258	267	269	253	244
60-00 Experiment Installation and Checkout	132	150	142	147	134
63-00 Spacelab Integration	42	35	36	35	44
66-00 Cargo Integration	24	25	24	24	25
70-00 GSE	4	4	4	4	4
Totals	631	654	639	627	610

Table 3.1-20. Per-Mission User Manpower Requirements for Mission-Unique Tasks (Man-Months)

WBS Task \ Concept	I	II & VII	III & VI	IV & VIII	V
30-00 Mission Analysis	25	25	62	62	63
40-00 Mission Operations	53	53	83	83	87
50-00 Systems Engineering	61	61	173	209	223
60-00 Experiment Installation and Checkout	6	6	74	144	134
63-00 Spacelab Integration	0	0	7	6	36
66-00 Cargo Integration	1	1	8	8	8
70-00 GSE	0	0	4	4	4
Totals	146	146	411	516	555

Table 3.1-21. Per Mission Integration Center Manpower Requirements for Mission-Unique Tasks (Man-Months)

WBS Task \ Concept	I	II & VII	III & VI
30-00 Mission Analysis	46	44	0
40-00 Mission Operations	38	32	0
50-00 Systems Engineering	176	162	52
60-00 Experiment Installation and Checkout	126	141	65
63-00 Spacelab Integration	34	6	0
66-00 Cargo Integration	8	8	0
70-00 GSE	4	4	0
Totals	432	397	117

Table 3.1-22. Per-Mission Launch Site Manpower Requirements for Mission-Unique Tasks (Man-Months)

WBS Task \ Concept	I	II&VII	III&VI	IV&VIII	V
30-00 Mission Analysis	7	10	10	10	7
40-00 Mission Operations	2	9	9	9	2
50-00 Systems Engineering	21	44	44	44	21
60-00 Experiment Installation and Checkout	0	3	3	3	0
63-00 Spacelab Integration	8	29	29	29	8
66-00 Cargo Integration	15	16	16	16	17
70-00 GSE	-	-	-	-	-
Totals	53	111	111	111	55

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3.2 MISSION-UNIQUE SUPPORT SERVICES

In addition to the personnel requirements for mission-unique functions, there are other supporting services that must be considered. Materials, personnel travel, computer facility operations, documentation, and flight hardware shipment must be estimated and included in the total resource requirements for mission-unique functions.

MATERIALS

Each ATL Spacelab mission will require the design and fabrication of cables, mounts, enclosures and mockups. The personnel estimates developed in Section 3.1 included the design and fabrication effort. The materials involved are a delta resource requirement.

Table 3.2-1 identifies those WBS tasks that will require mission-unique materials. The total requirements are the same for all concepts; only the cognizant center varies. The launch site is not required to furnish any mission-unique materials in any of the concepts. The material requirements of the two ATL configurations (complete Spacelab and pallet-only) are essentially the same for corresponding processing concepts and are as indicated in the table.

Table 3.2-1. Mission-Unique Material Requirements

WBS Task	Concept	I		II & VII		III & VI		IV & VIII	V
	Center	U	IC	U	IC	U	IC	U	U
50-60	Mockups		X		X	X		X	X
60-10-10	Cables		X		X		X	X	X
60-10-20	Structures		X		X		X	X	X
60-10-30	Protective Covers		X		X	X		X	X
70-10	Special Test Equip.		X		X	X		X	X

All mockups are considered to be "soft." Therefore, the associated materials are pressboard-plasterboard.

Cabling materials are for inter- and intra-rack/pallet and payload specialist station interconnections. Inter-module and Spacelab-Orbiter interconnecting cables are considered to be standard/furnished equipment. Cables to interconnect Spacelab modules and/or pallet to test equipment are considered to be part of the complement of GSE. But the connections from experiment equipment to GSE connectors must be provided as part of the mission-unique cabling/connections.

Structural materials include air-circulation baffles in rack enclosures, rack front panels, and sensor mounts. Standard items such as the inertial pointing system and airlocks are not included.

Some experiment equipment will require special handling during the integration process. Stringent cleanliness and unique vibration/acceleration isolation requirements will be accommodated by special environmental protection enclosures.

Special test equipment required by the individual experiments is assumed to be provided by the PI. But items of GSE that are required as a result of the integration process must be furnished by the integrator. For example, alignment and/or calibration of sensors mounted on either a single pallet section or multiple sections with respect to the Orbiter control axes will require mission-unique special test equipment that must be furnished by the integrator; special stands/fixtures may be required to mount/position PI-furnished calibration sources for end-to-end (sensor-to-data recorder) experiment tests.

PERSONNEL TRAVEL

Two categories of personnel travel were identified: supporting function liaison, and test and operations support. As the assumptions vary for the two types, they are defined separately.

Supporting Function Liaison

Included in the category of support function liaison are personnel trips for ICD coordination, engineering liaison, ground truth site operations, mission support, and safety reviews. Each identified trip is associated with a WBS task number. Round trips are always assumed.

Tables 3.2-2 through 3.2-6 summarize the supporting function trip requirements for all processing concepts. Management trips are not included. Principal investigator, discipline specialist, and payload specialist trips (including crew training) are not included. Trips for support of mission control operations are assumed to be 10 days in duration. Ground truth site trips (GT) reflect the periodic rotation of personnel at one or more remote sites. All other trips are estimated in terms of one man for two days.

Table 3.2-2. Concept I Support Function Travel Requirements

WBS	TASK	USER TO LS	USER TO IC	USER TO GT	IC TO LS	IC TO U	IC TO GT	LS TO IC
30.20.10	Operating Plans		2		1	1		1
30.20.20	Resource Allocation		2		1	1		1
30.20.30	Crew Timelines		1		1	2		1
30.30.10	Mission Plans		3		1	1		1
30.30.20	Operating Instructions (Sys)		2			1		
30.30.30	Ground Support Plans		2		1	1		
30.30.50	Training Plans		1			1		
40.10	Mission Control	1			2	1		
40.30.10	Ground Truth Site			20			20	
40.30.30	Spacelab Subsys. Support				2	1		
50.10.10.10	Performance Evaluation	1	2		1			
50.10.20.10	Flight/Ground Requirements		4		1	1		
50.10.30.10	Test Parameters		4		1	1		
50.10.40.10	GSE/Facility Requirements		2		1			
50.20.10.10	Oper. Instructions (Mission)	1	2		1			1
50.20.10.20	Equipment Specifications		2					
50.20.10.30	CPSE		2		1			1
50.20.30	ICD's		4		2	3		2
50.30.10.10	Orbiter Software				1			1
50.30.10.20	Spaclab/Expmt Software		2			2		
50.40.30	Reliability Inspection		1					
50.50.30	Safety Review		1					1
50.60	Mockup Design		1		1	2		
60.20	Level III Test Plans		6			2		
63.20	Level II Test Plans		3					
66.20	Level I Test Plans	2			4			1
66.40.10	Level I Safety Review	2			2			
	TOTALS	7	49	20	25	21	20	11
			76			66		
					153			

Table 3.2-3. Concepts II and VII Support Function Travel Requirements

WBS TASK	TRIP	USER TO LS	USER TO IC	USER TO GT	IC TO LS	IC TO U	IC TO GT	LS TO IC
30.20.10	Operating Plans		2		2	1		1
30.20.20	Resource Allocations		2		2	1		1
30.20.30	Crew Timelines		1		2	2		1
30.30.10	Mission Plans		3		2	1		1
30.30.20	Oper. Instructions (System)		2		2	1		1
30.30.30	Ground Support Plans		2		2	1		
30.30.50	Training Plans		1		1	1		
40.10	Mission Control	1			1			
40.30.10	Ground Truth Site			20			20	
40.30.30	Spacelab Subsys. Support							2
50.10.10.10	Performance Evaluation	2	2		2			
50.10.20.10	Flight/Ground Requirements		4		4	1		
50.10.30.10	Test Parameters	1	4		6	1		
50.10.40.10	GSE/Facility Requirements		2		2			
50.20.10.10	Oper. Instructions (Mission)	2	2		2			1
50.20.10.20	Equipment Specifications		2		2			1
50.20.10.30	CPSE		2		2			1
50.20.30.	ICD's	2	4		4	2		4
50.30.10.10	Orbiter Software				1			1
50.30.10.20	Spacelab/Expmt Software	2			4	2		
50.40.30	Reliability Inspection		1					
50.50.30	Safety Reviews		1					1
50.60	Mockup Design	2	1		2	2		
60.20	Level III Test Plans		6			2		
63.20	Level II Test Plans	2			4			1
66.20	Level I Test Plans	2			4			1
66.40.10	Level I Safety Review	2			2			
	TOTALS	18	44	20	55	18	20	18
			82			93		
				193				

Table 3.2-4. Concepts III and VI Support Function Travel Requirements

WBS TASK		USER TO LS	USER TO IC	USER TO GT	IC TO U	LS TO U
30.20.10	Operating Plans	2				1
30.20.20	Resource Allocations	2				1
30.20.30	Crew Timelines	2				1
30.30.10	Mission Plans	2				1
30.30.20	Operating Instructions (System)	2				1
30.30.30	Ground Support Plans	2				
30.30.50	Training Plans	1				
40.10	Mission Control	1				1
40.30.10	Ground Truth Site			30		
40.30.30	Spacelab Subsystem Support					2
50.10.10.10	Performance Evaluation	2				
50.10.20.10	Flight/Ground Requirements	4				
50.10.30.10	Test Parameters	6				
50.10.40.10	GSE/Facility Requirements	2	1			
50.20.10.10	Operating Instructions (Mission)	2				1
50.20.10.20	Equipment Specifications	2	1			1
50.20.10.30	CPSE	2	1			1
50.20.30	ICD's	4	2			4
50.30.10.10	Orbiter Software	1				1
50.30.10.20	Spacelab/Experiment Software	4				
50.40.30	Reliability Inspection				1	
50.50.30	Safety Reviews				1	1
50.60	Mockup Design	2	1			
60.20	Level III Test Plans		3		2	
63.20	Level II Test Plans	4				1
66.20	Level I Test Plans	4				1
66.40.10	Level I Safety Review	2				
	TOTALS	55	9	30	4	19
		94				
		117				

Table 3.2-5. Concepts IV and VIII Support Function Travel Requirements

WBS TASK		USER TO LS	USER TO GT	LS TO U
30.20.10	Operating Plans	2		1
30.20.20	Resource Allocations	2		1
30.20.30	Crew Timelines	2		1
30.30.10	Mission Plans	2		1
30.30.20	Operating Instructions (System)	2		1
30.30.30	Ground Support Plans	2		
30.30.50	Training Plans	1		
40.10	Mission Control	1		1
40.30.10	Ground Truth Site		30	
40.30.30	Spacelab Subsystem Support			2
50.10.10.10	Performance Evaluation	2		
50.10.20.10	Flight/Ground Requirements	4		
50.10.30.10	Test Parameters	6		
50.10.40.10	GSE Facility Requirements	2		
50.20.10.10	Operating Instructions (Mission)	2		1
50.20.10.20	Equipment Specifications	2		1
50.20.10.30	CPSE	4		1
50.20.30	ICD's	4		4
50.30.10.10	Orbiter Software	1		1
50.30.10.20	Spacelab/Experiment Software	4		
50.40.30	Reliability Inspection			
50.50.30	Safety Reviews			1
50.60	Mockup Design	2		
60.20	Level III Test Plans			
63.20	Level II Test Plans	4		1
66.20	Level I Test Plans	4		1
66.40.10	Level I Safety Review	2		
	TOTALS	57	30	19
		87		
		106		

Table 3.2-6. Concept V Support Function Travel Requirements

WBS TASK	TRIP	USER TO LS	USER TO GT	LS TO U
30.20.10	Operating Plans	1		1
30.20.20	Resource Allocations	1		1
30.20.30	Crew Timelines	1		1
30.30.10	Mission Plans	1		1
30.30.20	Operating Instructions (System)			
30.30.30	Ground Support Plans	1		
30.30.50	Training Plans			
40.10	Mission Control	2		
40.30.10	Ground Truth Site		30	
40.30.30	Spacelab Subsystem Support	2		
50.10.10.10	Performance Evaluation	1		
50.10.20.10	Flight/Ground Requirements	1		
50.10.30.10	Test Parameters	1		
50.10.40.10	GSE/Facility Requirements	1		
50.20.10.10	Operating Instructions (Mission)	1		1
50.20.10.20	Equipment Specifications			
50.20.10.30	CPSE	1		1
50.20.30	ICD's	2		2
50.30.10.10	Orbiter Software	1		1
50.30.10.20	Spacelab/Experiment Software			
50.40.30	Reliability Inspection			
50.50.30	Safety Reviews			1
50.60	Mockup Design	1		
60.20	Level III Test Plans			
63.20	Level II Test Plans			
66.20	Level I Test Plans	4		1
66.40.10	Level I Safety Review	2		
	TOTALS	25	30	11
		55		
		66		

Test and Operations Off-Site Travel Requirements

An integral part of the optimization of the processing concepts is the continuity of cognizant personnel throughout the integration cycle. One facet of that continuity is the off-site test engineering support that is included in the personnel estimates. Test engineers that conducted the test and operations at one level of integration participate in the next higher level of integration even if the higher level is performed at a different site.

Table 3.2-7 summarizes the required trips and trip durations to implement the proposed off-site support concept. Concepts I and V have the same requirements except for the cognizant center for the traveling personnel. The off-site support is related to Level I integration. The same similarity in requirements exists for Concepts II/VII and IV/VIII. Both Levels II and I integration support is involved. Concepts III and VI require two separate groups of personnel for off-site support. The first off-site support is associated with Level III integration at the user center. The second off-site support is associated with Levels II and I integration at the launch site.

Table 3.2-7. Travel Requirements for T&O Support

Concept	I	V	II/VII	IV/VIII	III/VI	
Trip	IC/LS	U/LS	IC/LS	U/LS	IC/U	U/LS
Number of personnel	3		2		2	3
Duration (days)	9		23		64	24

COMPUTER FACILITY OPERATIONS

It is anticipated that a significant quantityof flight software will be required for each mission. In addition, computer-aided designs, recordkeeping, and computer analysis will be used in accomplishing the supporting functions, test and operations, and data analysis. The summation of flight software development and computer-aided integration operations results in a requirement for significant support from off-line computer facilities.

Each WBS task was analyzed to establish an estimate of the actual running time that would be required of a large general-purpose computer such as the IBM 370. The estimates are presented in Table 3.2-8.

DOCUMENTATION

In the development of the mission-unique manpower estimates, the effort associated with the preparation of the technical contents of all required documents was also included. In subsequent paragraphs, the identification and definition of this documentation is presented. In addition to identifying which centers (user, IC, or LS) participate in the preparation of the documents, where appropriate, contributions by the PI's are also indicated. Documents are

Table 3.2-8. Mission-Unique Computer Facility Time Estimates (Hours)

WBS TASK \ CONCEPT / CENTER	I			II & V			III & VI			IV & VIII		V	
	U	IC	LS	U	IC	LS	U	IC	LS	U	LS	U	LS
30-10-20 ORBIT & TRAJ. ANALYSES	1	5	-	1	5	-	5	-	-	5	-	5	-
30-10-30 MISSION TIMELINES	1	5	1	1	5	1	5	-	1	5	1	5	1
30-20-20 RESOURCE ALLOCATIONS	-	2	.5	-	2	.5	2	-	.5	2	.5	2	.5
30-20-30 CREW TASK TIMELINES	1	5	.5	1	5	.5	5	-	.5	5	.5	5	.5
30-30-20 SYSTEM OPER. INSTRUCTIONS	-	2	-	-	2	.5	2	-	.5	2	.5	2	-
30-40-10 EXPMT FLIGHT DATA ANALYSIS	60	-	-	60	-	-	60	-	-	60	-	60	-
50-10-10-10 PERFORMANCE EVALUATION	-	4	-	-	4	-	4	-	-	4	-	4	-
50-10-10-20 EXPENDABLES	1	2	-	1	2	1	3	-	-	3	-	3	-
50-30-20-10 FLIGHT OPS. SOFTWARE	-	1	2	-	1	2	1	-	2	1	2	1	2
50-30-20-20 CHECKOUT & PERFORMANCE MONITOR SOFTWARE	3	5	-	3	5	-	8	-	-	8	-	8	-
50-30-20-40 REPAIR AND REFURBISH	-	.5	-	-	.1	.4	-	.1	.4	.1	.4	.5	-
50-80 CONFIGURATION CONTROL	-	1	-	-	.8	.2	.5	.3	.2	.8	.2	1	-
60-20-10 LEVEL III TEST PROCEDURES	-	4	-	-	4	-	4	-	-	4	-	4	-
63-20-10 LEVEL II TEST PROCEDURES	-	2	-	-	1	1	1	-	1	1	1	2	-
66-20-10 LEVEL I TEST PROCEDURES	-	1	.5	-	1	.5	1	-	.5	1	.5	1	.5
TOTALS	67	39.5	4.5	67	37.9	6.6	101.5	.4	6.6	101.9	6.6	103.5	4.5
	111			111.5			108.5			108.5		108	

classified as formal (inter-center) and informal (intra-center) as well as in-line (unique to the processing of a payload) and off-line (applicable to the general processing of Spacelab payloads).

Program Documentation

In order to establish the mission-unique integration and checkout documentation requirements, it was first necessary to develop a master payload integration program documentation list. The master list was developed by evaluating each WBS task description to determine if documentation requirements were applicable. Table 3.2-9 presents the master list by title and WBS number with a page estimate for each document. Table 3.2-10 presents a summary description of each document.

Some of the documents listed will be developed as part of the procedures to achieve operational status for the processing and integration of payloads with the Spacelab and Orbiter. These documents are identified as "off-line" requirements. Other documents in the list will be required for each mission and are identified as "in-line" requirements. The significance of the two classifications is in the estimated effort to revise/prepare the documents for each payload. The off-line documents will require minor updates for each mission. It is estimated that these updates will be equivalent to five percent of the effort to develop the initial issue. In-line documents must be prepared and issued uniquely for each payload. But a learning curve in documentation preparation can be assumed. Basic format and procedures will be essentially the same for each payload. Reflight of experiments plus the standardized interfaces of the Spacelab and Orbiter will expedite the development of mission-unique in-line documentation. A truncated learning curve of 95 percent is a reasonable assumption. That is, a 5-percent reduction in the effort to develop each succeeding set of in-line documents can be assumed until the required mission-unique effort is 50 percent of the initial release effort. The manpower requirements associated with the applicable WBS entries reflect these off-line and in-line documentation assumptions.

An additional factor in determining the effort associated with the preparation of the required documentation is the coordination-review-approval cycle to which each document will be subjected. The three levels of documentation considered were:

1. *FORMAL.* Inter-center agreements requiring multi-center management review and approval.

2. *INFORMAL.* Intra-center agreements with localized control.

3. *SUPPORT.* Either inter- or intra-center data transfer or review for purpose of information exchange or notification of plans and activities. The routine interchange and correlation of engineering data.

Table 3.2-9. Payload Integration Documentation Requirements

	TITLE	PAGE EST.	WBS NUMBER	IN-LINE	OFF-LINE
1.	MASTER PROGRAM PLAN & SCHEDULE	50	10-20-10-00		X
2.	CONFIGURATION MANAGEMENT REPORT (MONTHLY)	50	10-30-00-00	X	
3.	LOGISTICS PLAN	100	20-10-10-00		X
4.	INVENTORY REPORT	50	20-10-40-00	X	
5.	EXPERIMENT REQUIREMENTS	100	30-10-10-00	X	
6.	RESOURCE ALLOCATION PLANS	200	30-20-20-00	X	
7.	MISSION FLIGHT PLAN	200	30-30-10-00	X	
8.	EXPERIMENT OPERATING INSTRUCTIONS	200	30-30-20-00	X	
9.	GROUND SUPPORT PLAN	200	30-30-30-00	X	
10.	MISSION TURNAROUND AND REFURBISHMENT PLAN	200	30-30-50-00		X
11.	DATA REDUCTION REPORT	100	30-40-20-00	X	
12.	TRAINING PLAN AND PROCEDURES	200	30-50-10-00	X	
13.	INSTRUMENTATION LIST	50	50-10-10-20	X	
14.	EXPERIMENT RESOURCE REQUIREMENTS	100	50-10-10-20	X	
15.	EMC (TEST REQUIREMENTS) PLAN	200	50-10-10-30		X
16.	SPACELAB USER'S GUIDE	100	50-10-10-40		X
17.	EXPERIMENTER'S DESIGN MANUAL	200	50-10-10-40		X
18.	TEST REQUIREMENTS	200	50-10-30-10	X	
19.	GSE AND FACILITIES PLAN	200	50-10-40-00		X
20.	SYSTEM REQUIREMENTS MANUAL	400	50-20-10-00	X	
21.	EQUIPMENT SPECIFICATIONS	400	50-20-10-10	X	
22.	EQUIPMENT OPERATING INSTRUCTIONS	200	50-20-10-10	X	
23.	INSTALLATION LAYOUT DRAWING	100	50-20-20-10	X	
24.	CRITICAL DESIGN REVIEW (CDR)	100	50-20-20-00	X	
25.	MASS PROPERTIES REPORT (SPACELAB & EXPMTS--MONTHLY)	50	50-20-20-10	X	
26.	INTERFACE CONTROL DOCUMENTS (4)	100	50-20-30-00		X
27.	SOFTWARE REQUIREMENTS	100	50-30-10-10	X	
28.	DATA REQUIREMENTS REPORT	50	50-30-10-20	X	
29.	RELIABILITY, MAINTENANCE PROGRAM PLAN	50	50-40-10-00		X
30.	FAILURE MODES EFFECTS ANALYSIS (FMEA)	100	50-40-20-00	X	
31.	SAFETY STANDARDS AND CRITERIA (SYSTEMS SAFETY PLAN--SSP)	100	50-50-10-00		X
32.	INDIVIDUAL TEST PROCEDURES				
	A. EXPERIMENT INSTALLATION AND CHECKOUT	50	60-20-10-00	X	
	B. SPACELAB INTEGRATION	50	63-20-10-00	X	
	C. CARGO INTEGRATION	50	66-20-20-00	X	
33.	TEST SUMMARY REPORTS (8)				
	A. EXPERIMENT INSTALLATION AND CHECKOUT	50	60-20-10-00	X	
	B. SPACELAB INTEGRATION	50	63-20-10-00	X	
	C. CARGO INTEGRATION	50	66-20-20-00	X	
34.	TEST DATA REPORTS				
	A. EXPERIMENT INSTALLATION AND CHECKOUT	50	60-20-10-00	X	
	B. SPACELAB INTEGRATION	50	63-20-10-00	X	
	C. CARGO INTEGRATION	50	66-20-20-00	X	
35.	FAILURE SUMMARY REPORTS				
	A. EXPERIMENT INSTALLATION AND CHECKOUT	50	60-20-10-00	X	
	B. SPACELAB INTEGRATION	50	63-20-10-00	X	
	C. CARGO INTEGRATION	50	66-20-20-00	X	

Table 3.2-10. Description of Program Documentation

Title	Remarks
1. MASTER PROGRAM PLAN & SCHEDULE	Provides visibility with milestones which represent the significant steps necessary to accomplish program objectives, and against which progress may be measured. The user shall prepare a master summary schedule which shall establish: (1) the planned manpower buildup requirements for performance of the program objectives; (2) a planned program for accomplishing the pertinent planning, research, study actions, or steps required to complete program objectives; (3) milestones based upon significant steps or points of accomplishment; and (4) the time span, including applicable starting and completion dates, for each of the above items. A revision to the schedule shall be issued to all interested groups, with supporting information, at any time that significant changes are required.
2. CONFIGURATION MANAGEMENT REPORT	A plan that establishes provisions for maintenance and control of the equipment status of the Spacelab and experiments will be prepared. It includes a system for identification of each element, its composition, and the location and timing as well as the nature of each process, test, or use. This document will be issued for each mission, released at the completion of experiment installation and updated at the completion of all testing prior to Orbiter-cargo integration. This updated version will the then represent the "as-tested" configuration that is shipped to the launch site and subsequently flown on the next mission.
3. LOGISTICS PLAN	The Logistics Plan is to provide in a single top-level document the overall logistics requirements necessary to support a specific mission. The initial logistics plan should be published 12 to 18 months prior to the mission launch date, and updated or supplemented as required. As a minimum, the document will cover: 1. *Logistics Responsibilities.* Responsibilities of each center (or site) pertaining to the logistics functional areas of maintenance, provisioning of spares, supply support, technical data, transportation and handling. These areas will be developed as necessary to ensure support for the assembly, checkout, refurbishment, transport, test operations, and prelaunch, launch, and post-landing logistics activities. 2. *Support Implementation.* Flow diagrams for each major hardware item (GSE or Spacelab module) reflecting logistics support activities by time and location, including the identification of inter-center logistics interfaces. 3. *Support Assessment.* Assessment of the overall logistics support for a particular mission. This measure is made against T&O flows to identify any potential problem areas that may exist. Actions pending or in progress to correct any logistics deficiency will be included.
4. INVENTORY REPORT	This report provides program management with the status of the logistics for a particular mission. It shall provide the assessment of the logistics activity (at each spares provisioning or equipment storage facility) in the following categories: (1) logistics support integration (planning and implementation), (2) spares provisioning, (3) supply support, (4) launch-critical spares status, (5) transportation of major program end items (SM/EM/P, etc.), (6) storage of major program end items, (7) GSE operations and maintenance instructions, and (8) logistics training program. This inventory portion of the report shall be prepared by each center where spares have been selected for storage. It shall contain at least the following data: spares item numbers including titles and descriptions, quantities on hand, and a recommended reordering plan.

Table 3.2-10. Description of Program Documentation (Cont)

Title	Remarks
5. EXPERIMENT REQUIREMENTS	This document is a summary report that defines the objectives, requirements and constraints which the experiments will impose on the conduct of the flight and associated ground support operations. This includes definition of such items as target locations, range, line of sight, attitude, stability requirements, data output, and ground truth requirements. There will be one of these documents for each mission; it should be released at launch minus 15 months.
6. RESOURCE ALLOCATION PLAN	This document will contain the results of the analyses to optimize the allocation of resources in support of missions and associated ground operations. The resources include personnel, GSE, communications, data processing facilities, supporting ground truth sites, aircraft, monitoring and control stations, equipment and other supporting items.
7. MISSION FLIGHT PLAN	This document is a complete plan for flight operations. The plan will include mission objectives, experiment equipment identification, orbit and trajectory profiles, crew timelines, experiment operating sequences, target locations, safety requirements, contingency plans, etc.
8. EXPERIMENT OPERATING INSTRUCTIONS	This document will contain step-by-step instructions for operating the experiment in conjunction with Spacelab equipment during flight. These include operating steps, checklists, anticipated parameter values and limits, hazards, recycling sequences, coordination with ground operations, etc.
9. GROUND SUPPORT PLAN	This purpose of this plan is to describe the role and approach to the activities necessary to prepare for the accomplishment of the ground operations during flight. The plan shall describe the activities, requirements, constraints, limits, and goals required for all ground operations from launch to landing and any major equipment items, including operations control center, ground targets, and ground truth sites.
10. MISSION TURNAROUND AND REFURBISHMENT PLAN	This document will define the requirements and procedures that will be utilized during the refurbishment and reconfiguring of Spacelab modules. The document will contain the definition of the refurbishment plans and requirements of the SM, EM, R, P, and the support subsystems and the disposition of the experiment equipment.
11. DATA REDUCTION REPORT	This report contains an analysis of the support systems data derived from flights. It is an assessment of the problems and system peculiarities that were observed during the flight and post-flight data processing. It is not the experimenters' analyses or reports of experiment performance.
12. TRAINING PLAN AND PROCEDURES	These two items will be necessary to establish the training requirements that exist for each mission. The training plan will detail the steps that must be accomplished in order to provide the required training. The procedures will detail the training and familiarization of the payload specialists with the individual experimenters and their equipment.
13. INSTRUMENTATION LIST	Each mission will require a new instrumentation list that contains the required details of the experiment equipment complement for that given flight. The list will include sensor information relating to location, type, calibration, and special processing identification numbers, so that these data can be extracted from telemetry. It includes both subsystem equipment (on SM or pallet) and experiment data.
14. EXPERIMENT RESOURCE REQUIREMENTS	This document is an accumulation of the total complement of support requirements for a mission. It will include expendable schedules, power profiles, alignment/pointing histories, and other schedules that affect the support services of the Orbiter and Spacelab.

Table 3.2-10. Description of Program Documentation (Cont)

Task	Remarks
15. EMC (TEST REQUIREMENTS) PLAN	This document contains the definition, analyses, and constraints for the suppression/reduction of both radiated and conducted electromagnetic interference to tolerable levels. Peak power, spectral densities, and usable frequency bands will be specified.
16. SPACELAB USER'S GUIDE	This document will delineate the compatibility of support capability of the Spacelab and Orbiter. It will detail this capability both in terms of the subsystems accommodations available during the mission and the ground processing and checkout capability that exists.
17. EXPERIMENTER DESIGN MANUAL	This document will provide potential PI's with the basic design data to ensure that their equipment design is compatible with the physical, mechanical and electrical accommodations of the Orbiter and the Spacelab. Specific data on material selection, safety requirements and design restrictions will also be included.
18. TEST REQUIREMENTS	This document will be a compilation of the detail requests for testing. Specific tests required, parameters to be verified, and the specification of performance and test parametric values and tolerances will be included.
19. GSE AND FACILITIES PLAN	This document will list the GSE and facility requirements envisioned for the ATL program. It will also identify specific pieces of equipment required, model numbers, equipment capability, intended use, location and quantities required. The document will also establish the delta requirements and modifications to existing GSE for each mission. These mission-by-mission changes will be added as addendums to the basic plan. The scope of the plan covers the entire period that an experiment/rack/payload is undergoing some aspect of the processing cycle from receipt at the user's facility through test and checkout, launch preparations, and post-flight operations.
20. SYSTEMS REQUIREMENTS MANUAL	This manual will delineate and control the integration of experiment equipment, common payload support equipment, interface hardware, support system interfaces, and volume/mass allocations. It is the top-level design control document for the integration of all equipment in the Spacelab modules and on the pallet sections.
21. EQUIPMENT SPECIFICATION	This document is a compilation of the design, fabrication, and test requirements for the various items of interfacing equipment that are required for each mission. Items included are intra-rack cabling, support structures, routing pedestals, air baffles, protective covers, and auxiliary panel mounts.
22. EQUIPMENT OPERATING INSTRUCTIONS	This set of operating instructions correlates the individual experiment operating instructions with the integrated payload mechanization. The instructions reflect the usage of Spacelab and Orbiter support systems, common payload support equipment and the required interfacing hardware with the experiment equipment in the installed/integrated configuration.
23. INSTALLATION LAYOUT DRAWINGS	For each payload, a detailed set of instructions for the physical installation of experiment, CPSS and PSS equipment in the racks, on the pallet, in the SM and in the Orbiter are required. This series of drawings, which will include electrical and fluid interconnections, will be the document that provides these instructions.
24. CRITICAL DESIGN REVIEW (CDR)	In order to describe the design effort associated with experiment installation in the Spacelab, there will be two design reviews. At 50-percent drawing release, there will be a preliminary design review (PDR), and at 90-percent release there will be a critical design review (CDR). It is at this point that the layout of experiments, common controls and displays and interface hardware will be reviewed and approved. The CDR document will be a collection of the final approved design drawing. It will also include any pertinent notes or comments that are important in the modification of existing equipment or the development of new interface hardware. Any changes to cable runs, utilities distribution, plumbing or ducting will be governed by the installation layout drawing (see Item 23).

Table 3.2-10. Description of Program Documentation (Cont)

Title	Remarks
25. MASS PROPERTIES REPORT	The purpose of this report will be to provide the operations planning groups with the updated Spacelab and experiments' weights, c.g.'s, and the final installation location for all experiments. All consumables required to be loaded for the Spacelab will also be included. Monthly updates, commencing with fabrication of interface hardware, will be required.
26. INTERFACE CONTROL DOCUMENTS (ICD's)	Four basic ICD's will be written: (1) Mechanical, (2) Electrical, (3) Fluid/Pneumatics, and (4) Procedural. They will establish and define the interfaces between the experiments and the Spacelab and the Shuttle, required to satisfy a mission. The purpose of each ICD is to ensure compatibility by documenting form, fit and function. Pre-integration agreements are required to satisfy installation, connection, checkout, and subsequent orbital mission objectives.
27. SOFTWARE PLAN	This document will contain the software requirements for the integration effort. The plan will contain software requirements for three specific mission phases: ground checkout, in-flight status and operation, and data processing (both post-flight and real time). The plan will contain data on both the systems routines (programs that are utilized for many experiments on multiple missions), software modifications to existing programs for unique applications, and individual experiment-unique program requirements.
28. DATA REQUIREMENTS REPORT	This report will be an integration of all the experiment and support systems engineering data and formats required for pre-flight and flight evaluations. This document will detail final groupins, special plotting, and data processing for PI's or integration personnel. The document will have two major sections: checkout processing requirements, and flight data processing requirements.
29. RELIABILITY/ MAINTAIN-ABILITY PROGRAM PLAN	Based upon the reliability/maintainability plan for the Spacelab and Orbiter, the Spacelab user shall develop a plan tailored to the goals and objectives of the experiments of a given payload. Reliability and maintainability requirements for experiments may be significantly different than those for the Spacelab or Orbiter, provided neither operational capability nor crew safety is jeopardized.
30. FAILURE MODE EFFECTS ANALYSIS (FMEA)	This document will be the report published for each mission after the experiment equipment designs have been reviewed and evaluated. It represents the numerical analysis of reliability, failure mode effects analysis (FMEA), failure reporting, and other data compilation and analytical work relating to the reliability, maintainability, and quality control provisions adopted in individual experiment equipment and integrated payload design.
31. SAFETY STANDARDS & CRITERIA (SYSTEM SAFETY PLAN)	The system safety plan will describe the safety requirements for program participants. The plan will emphasize the controls that are required to assure effective systems and procedures to identify hazards and maximize the safety of personnel and equipment during all program phases, especially in their relationship to flight operations.
32. INDIVIDUAL OPERATIONAL CHECKOUT PROCEDURES	Operational checkout procedures (OCP's) will be required for the following tests: (1) experiment installation and checkout, (2) Spacelab integration, and (3) cargo integration. These procedures will be the step-by-step instructions for conducting the tests and operations on the experiments and Spacelab through integration (1, 2, and 3, above). These test procedures are derived from the test requirements and are utilized to direct an orderly, efficient test or operation. They will specify: test objectives, timelines, step-by-step procedures, personnel required, GSE required, support requirements (organization and facilities), constraints, safety hazards, and emergency procedures (in the event of failure during test).

Table 3.2-10. Description of Program Documentation (Cont)

Title	Remarks
33. TEST SUMMARY SHEETS	For each major test that is run, summary sheets of the data generated during the test are required. These may be from CRT observations, master readings, strip charts or photos. Any other data processed either in real time or post-test that were used to verify performance will be reported on these sheets. The test summary sheets will accompany a marked-up copy of the "as-run" operational checkout procedure (OCP). These data, when coupled with the test conductor's comments, QC notes, dispositioned discrepancy reports (DR's), and the signed non-conformance reports (NCR's) will form the final data package for the particular test just completed. As a minimum, there will be three such sets--one for experiment installation and checkout, a second for Spacelab integration and, finally, the Orbiter cargo integration set.
34. TEST DATA QUALITY REPORTS	Following successful completion of a test, a test data report that summarizes the analysis of the data and results is prepared. There will be a separate report generated for each major test conducted. These data reports are submitted for review and approval by program management to determine the flight-readiness of the payload.
35. FAILURE SUMMARY REPORT	Failures or out-of-tolerance conditions, experienced during any phase of the T&O process, will be documented and resolution submitted as soon as possible after each occurrence. The documentation will describe the event and supporting data that describe the discrepancy, resolution, and/or recommended follow-up action.

Concept Requirements

The documentation levels are concept-dependent. Tables 3.2-11 through 3.2-15 indicate the applicable levels for each document for each processing concept for both the off-line and in-line classes of documents. The center responsible for the issuance of the document is identified either by "F" (formal) or "I" (informal). Where applicable, other involved centers are identified by "S" (support). Principal investigator support is also indicated.

The similarity in the processing activities and requirements between the pallet-only concepts (VI, VII, and VIII) and three of the complete Spacelab concepts (III, II, and IV, respectively) resulted in identical documentation requirements for the comparable processing concepts.

Documentation Summary

A compilation of documentation requirements by center and by concept is presented in Table 3.2-16. The variation in the total number of off-line and in-line documents is indicative of the number of centers involved in the integration and checkout activities. Integration center requirements are approximately the same for Concepts I and II/VII and are reduced by a factor of about 4 in Concept III/VI, where the user center assumes almost all of the integration and checkout responsibility. Launch site requirements reflect the ownership variation of the support module/systems igloo. User total requirements are relatively constant for all concepts. The significant difference is the type of documentation required. In Concepts I and II/VII, numerous formal documents that are supported by the user center are required. As the user center assumes more of the responsibility, the total number of documents may not vary but the type of documentation does. Only intra-center coordination/approval is required and, therefore, the majority of the documents become informal. PI support requirements are the same for all concepts. This consistency reflects the approach that the user center is the PI's representative during the integration process, but the PI's remain involved in the activities.

Table 3.2-11. Concept I Documentation Requirements

	UNIT NO.	DOCUMENT TITLE	IC	LS	U	PI
OFF LINE	1	MASTER PROGRAM PLAN & SCHEDULE	S	S	F	S
	3	LOGISTICS PLAN	F	S	S	S
	10	MISSION TURNAROUND AND REFURBISHMENT PLAN	I		S	S
	15	EMC (TEST REQUIREMENTS) PLAN	F	S		
	16	SPACELAB USER'S GUIDE	F	S		
	17	EXPERIMENTER'S DESIGN MANUAL	I	S		
	19	GSE AND FACILITIES PLAN	F	S		
	26	INTERFACE CONTROL DOCUMENTS	F	F	S	
	29	RELIABILITY, MAINTENANCE PROGRAM PLAN	F		S	S
	31	SAFETY STANDARDS AND CRITERIA	F	S	S	S
IN LINE	2	CONFIGURATION MANAGEMENT REPORT	I	S	S	S
	4	INVENTORY REPORT	I	S		
	5	EXPERIMENT REQUIREMENTS			I	S
	6	RESOURCE ALLOCATION PLANS	I	S	S	
	7	MISSION FLIGHT PLAN	F	S	S	S
	8	EXPERIMENT OPERATING INSTRUCTIONS	F		S	S
	9	GROUND SUPPORT PLAN	F		S	S
	11	DATA REDUCTION REPORT	I	S	S	
	12	TRAINING PLAN AND PROCEDURES			I	S
	13	INSTRUMENTATION LIST	F		S	S
	14	EXPERIMENT RESOURCE REQUIREMENTS			I	S
	18	TEST REQUIREMENTS			I	S
	20	SYSTEM REQUIREMENTS MANUAL	F		S	
	21	EQUIPMENT SPECIFICATION	F		S	
	22	EQUIPMENT OPERATING INSTRUCTIONS	F		S	S
	23	INSTALLATION LAYOUT DRAWING	F		S	S
	24	CRITICAL DESIGN REVIEW (CDR)	F	S	S	S
	25	MASS PROPERTIES REPORT	I		S	
	27	SOFTWARE REQUIREMENTS	F		S	S
	28	DATA REQUIREMENTS REPORT			I	S
	30	FAILURE MODES EFFECTS ANALYSIS (FMEA)			I	S
	32	INDIVIDUAL TEST PROCEDURES				
		A. EXPERIMENT INSTALLATION AND CHECKOUT	F		S	S
		B. SPACELAB INTEGRATION	F	S	S	
		C. CARGO INTEGRATION	S	F	S	
	33	TEST SUMMARY REPORTS				
		A. EXPERIMENT INSTALLATION AND CHECKOUT	I			
		B. SPACELAB INTEGRATION	I			
		C. CARGO INTEGRATION		I		
	34	TEST DATA REPORTS				
		A. EXPERIMENT INSTALLATION AND CHECKOUT	F		S	S
		B. SPACELAB INTEGRATION	F	S	S	
		C. CARGO INTEGRATION	S	F	S	
	35	FAILURE SUMMARY REPORTS				
		A. EXPERIMENT INSTALLATION AND CHECKOUT	F		S	S
		B. SPACELAB INTEGRATION	F	S	S	
		C. CARGO INTEGRATION	S	F	S	

Table 3.2-12. Concept II/VII Documentation Requirements

	UNIT NO.	DOCUMENT TITLE	IC	LS	U	PI
OFF LINE	1	MASTER PROGRAM PLAN & SCHEDULE	S	S	F	S
	3	LOGISTICS PLAN	F	S	S	S
	10	MISSION TURNAROUND AND REFURBISHMENT PLAN	F	S	S	S
	15	EMC (TEST REQUIREMENTS) PLAN	F	S		
	16	SPACELAB USER'S GUIDE	F	S		
	17	EXPERIMENTER'S DESIGN MANUAL	I	S		
	19	GSE AND FACILITIES PLAN	F	S		
	26	INTERFACE CONTROL DOCUMENTS	F	F	S	
	29	RELIABILITY, MAINTENANCE PROGRAM PLAN	F		S	S
	31	SAFETY STANDARDS AND CRITERIA	F	S	S	S
IN LINE	2	CONFIGURATION MANAGEMENT REPORT	I	S	S	S
	4	INVENTORY REPORT	I	S		
	5	EXPERIMENT REQUIREMENTS			I	S
	6	RESOURCE ALLOCATION PLANS	I	S	S	
	7	MISSION FLIGHT PLAN	F	S	S	S
	8	EXPERIMENT OPERATING INSTRUCTIONS	F	S	S	S
	9	GROUND SUPPORT PLAN	F		S	S
	11	DATA REDUCTION REPORT	S	I	S	
	12	TRAINING PLAN AND PROCEDURES			I	S
	13	INSTRUMENTATION LIST	F	S	S	S
	14	EXPERIMENT RESOURCE REQUIREMENTS			I	S
	18	TEST REQUIREMENTS			I	S
	20	SYSTEM REQUIREMENTS MANUAL	F	S	S	
	21	EQUIPMENT SPECIFICATION	F	S	S	
	22	EQUIPMENT OPERATING INSTRUCTIONS	F	S	S	S
	23	INSTALLATION LAYOUT DRAWING	F		S	S
	24	CRITICAL DESIGN REVIEW (CDR)	F	S	S	S
	25	MASS PROPERTIES REPORT	I		S	
	27	SOFTWARE REQUIREMENTS	F		S	S
	28	DATA REQUIREMENTS REPORT			I	S
	30	FAILURE MODES EFFECTS ANALYSIS (FMEA)			I	S
	32	INDIVIDUAL TEST PROCEDURES				
		A. EXPERIMENT INSTALLATION AND CHECKOUT	F		S	S
		B. SPACELAB INTEGRATION	S	F	S	
		C. CARGO INTEGRATION	S	F	S	
	33	TEST SUMMARY REPORTS				
		A. EXPERIMENT INSTALLATION AND CHECKOUT	I			
		B. SPACELAB INTEGRATION		I		
		C. CARGO INTEGRATION		I		
	34	TEST DATA REPORTS				
		A. EXPERIMENT INSTALLATION AND CHECKOUT	F		S	S
		B. SPACELAB INTEGRATION	S	F	S	
		C. CARGO INTEGRATION	S	F	S	
	35	FAILURE SUMMARY REPORTS				
		A. EXPERIMENT INSTALLATION AND CHECKOUT	F		S	S
		B. SPACELAB INTEGRATION	S	F	S	
		C. CARGO INTEGRATION	S	F	S	

Table 3.2-13. Concept III/VI Documentation Requirements

	UNIT NO.	DOCUMENT TITLE	IC	LS	U	PI
OFF LINE	1	MASTER PROGRAM PLAN & SCHEDULE	S	S	F	S
	3	LOGISTICS PLAN	S	S	F	S
	10	MISSION TURNAROUND AND REFURBISHMENT PLAN	F	S	S	S
	15	EMC (TEST REQUIREMENTS) PLAN		S	F	
	16	SPACELAB USER'S GUIDE		S	F	
	17	EXPERIMENTER'S DESIGN MANUAL	S	S	I	
	19	GSE AND FACILITIES PLAN	S	S	F	
	26	INTERFACE CONTROL DOCUMENTS	S	F	F	
	29	RELIABILITY, MAINTENANCE PROGRAM PLAN			I	S
	31	SAFETY STANDARDS AND CRITERIA	S	S	F	S
IN LINE	2	CONFIGURATION MANAGEMENT REPORT	S	S	I	S
	4	INVENTORY REPORT	S	S	I	
	5	EXPERIMENT REQUIREMENTS			I	S
	6	RESOURCE ALLOCATION PLANS		S	I	
	7	MISSION FLIGHT PLAN		S	F	S
	8	EXPERIMENT OPERATING INSTRUCTIONS		S	F	S
	9	GROUND SUPPORT PLAN			I	S
	11	DATA REDUCTION REPORT		I	S	
	12	TRAINING PLAN AND PROCEDURES			I	S
	13	INSTRUMENTATION LIST		S	F	S
	14	EXPERIMENT RESOURCE REQUIREMENTS			I	S
	18	TEST REQUIREMENTS			I	S
	20	SYSTEM REQUIREMENTS MANUAL	F	S	S	
	21	EQUIPMENT SPECIFICATION	F	S	S	
	22	EQUIPMENT OPERATING INSTRUCTIONS	S	S	F	S
	23	INSTALLATION LAYOUT DRAWING	F		S	S
	24	CRITICAL DESIGN REVIEW (CDR)		S	F	S
	25	MASS PROPERTIES REPORT			I	
	27	SOFTWARE REQUIREMENTS			I	S
	28	DATA REQUIREMENTS REPORT			I	S
	30	FAILURE MODES EFFECTS ANALYSIS (FMEA)			I	S
	32	INDIVIDUAL TEST PROCEDURES				
		A. EXPERIMENT INSTALLATION AND CHECKOUT			I	S
		B. SPACELAB INTEGRATION		F	S	
		C. CARGO INTEGRATION		F	S	
	33	TEST SUMMARY REPORTS				
		A. EXPERIMENT INSTALLATION AND CHECKOUT			I	
		B. SPACELAB INTEGRATION		I		
		C. CARGO INTEGRATION		I		
	34	TEST DATA REPORTS				
		A. EXPERIMENT INSTALLATION AND CHECKOUT			I	S
		B. SPACELAB INTEGRATION		F	S	
		C. CARGO INTEGRATION		F	S	
	35	FAILURE SUMMARY REPORTS				
		A. EXPERIMENT INSTALLATION AND CHECKOUT			I	S
		B. SPACELAB INTEGRATION		F	S	
		C. CARGO INTEGRATION		F	S	

Table 3.2-14. Concept IV/VIII Documentation Requirements

	UNIT NO.	DOCUMENT TITLE	LS	U	PI
OFF LINE	1	MASTER PROGRAM PLAN & SCHEDULE	S	F	S
	3	LOGISTICS PLAN	S	F	S
	10	MISSION TURNAROUND AND REFURBISHMENT PLAN	S	F	S
	15	EMC (TEST REQUIREMENTS) PLAN	S	F	
	16	SPACELAB USER'S GUIDE	S	F	
	17	EXPERIMENTER'S DESIGN MANUAL	S	I	
	19	GSE AND FACILITIES PLAN	S	F	
	26	INTERFACE CONTROL DOCUMENTS	F	F	
	29	RELIABILITY, MAINTENANCE PROGRAM PLAN		I	S
	31	SAFETY STANDARDS AND CRITERIA	S	F	S
IN LINE	2	CONFIGURATION MANAGEMENT REPORT	S	I	S
	4	INVENTORY REPORT	S	I	
	5	EXPERIMENT REQUIREMENTS		I	S
	6	RESOURCE ALLOCATION PLANS	S	I	
	7	MISSION FLIGHT PLAN	S	F	S
	8	EXPERIMENT OPERATING INSTRUCTIONS	S	F	S
	9	GROUND SUPPORT PLAN		I	S
	11	DATA REDUCTION REPORT	I	S	
	12	TRAINING PLAN AND PROCEDURES		I	S
	13	INSTRUMENTATION LIST	S	F	S
	14	EXPERIMENT RESOURCE REQUIREMENTS		I	S
	18	TEST REQUIREMENTS		I	
	20	SYSTEM REQUIREMENTS MANUAL	S	I	
	21	EQUIPMENT SPECIFICATION	S	I	
	22	EQUIPMENT OPERATING INSTRUCTIONS	S	F	S
	23	INSTALLATION LAYOUT DRAWINGS		I	S
	24	CRITICAL DESIGN REVIEW (CDR)	S	F	S
	25	MASS PROPERTIES REPORT		I	
	27	SOFTWARE REQUIREMENTS		I	S
	28	DATA REQUIREMENTS REPORT		I	S
	30	FAILURE MODES EFFECTS ANALYSIS (FMEA)		I	S
	32	INDIVIDUAL TEST PROCEDURES			
		A. EXPERIMENT INSTALLATION AND CHECKOUT		I	S
		B. SPACELAB INTEGRATION	F	S	
		C. CARGO INTEGRATION	F	S	
	33	TEST SUMMARY REPORTS			
		A. EXPERIMENT INSTALLATION AND CHECKOUT		I	
		B. SPACELAB INTEGRATION	I		
		C. CARGO INTEGRATION	I		
	34	TEST DATA REPORTS			
		A. EXPERIMENT INSTALLATION AND CHECKOUT		I	S
		B. SPACELAB INTEGRATION	F	S	
		C. CARGO INTEGRATION	F	S	
	35	FAILURE SUMMARY REPORTS			
		A. EXPERIMENT INSTALLATION AND CHECKOUT		I	S
		B. SPACELAB INTEGRATION	F	S	
		C. CARGO INTEGRATION	F	S	

Table 3.2-15. Concept V Documentation Requirements

	UNIT NO.	DOCUMENT TITLE	LS	U	PI
OFF LINE	1	MASTER PROGRAM PLAN & SCHEDULE	S	F	S
	3	LOGISTICS PLAN	S	F	S
	10	MISSION TURNAROUND AND REFURBISHMENT PLAN	S	I	S
	15	EMC (TEST REQUIREMENTS) PLAN	S	F	
	16	SPACELAB USER'S GUIDE	S	I	
	17	EXPERIMENTER'S DESIGN MANUAL		I	
	19	GSE AND FACILITIES PLAN	S	F	
	26	INTERFACE CONTROL DOCUMENTS	F	F	
	29	RELIABILITY, MAINTENANCE PROGRAM PLAN		I	S
	31	SAFETY STANDARDS AND CRITERIA	S	F	S
IN LINE	2	CONFIGURATION MANAGEMENT REPORT	S	I	S
	4	INVENTORY REPORT	S	I	
	5	EXPERIMENT REQUIREMENTS		I	S
	6	RESOURCE ALLOCATION PLANS	S	I	
	7	MISSION FLIGHT PLAN	S	F	S
	8	EXPERIMENT OPERATING INSTRUCTIONS		F	S
	9	GOUND SUPPORT PLAN		I	S
	11	DATA REDUCTION REPORT	S	I	
	12	TRAINING PLAN AND PROCEDURES		I	S
	13	INSTRUMENTATION LIST		I	S
	14	EXPERIMENT RESOURCE REQUIREMENTS		I	S
	18	TEST REQUIREMENTS		I	S
	20	SYSTEM REQUIREMENTS MANUAL		I	
	21	EQUIPMENT SPECIFICATION		I	
	22	EQUIPMENT OPERATING INSTRUCTIONS		I	S
	23	INSTALLATION LAYOUT DRAWINGS		I	S
	24	CRITICAL DESIGN REVIEW (CDR)	S	F	S
	25	MASS PROPERTIES REPORT		I	
	27	SOFTWARE REQUIREMENTS		I	S
	28	DATA REQUIREMENTS REPORT		I	S
	30	FAILURE MODES EFFECTS ANALYSIS (FMEA)		I	S
	32	INDIVIDUAL TEST PROCEDURES			
		A. EXPERIMENT INSTALLATION AND CHECKOUT		I	S
		B. SPACELAB INTEGRATION	S	I	
		C. CARGO INTEGRATION	F	S	
	33	TEST SUMMARY REPORTS			
		A. EXPERIMENT INSTALLATION AND CHECKOUT		I	
		B. SPACELAB INTEGRATION		I	
		C. CARGO INTEGRATION	I		
	34	TEST DATA REPORTS			
		A. EXPERIMENT INSTALLATION AND CHECKOUT		I	S
		B. SPACELAB INTEGRATION	S	I	
		C. CARGO INTEGRATION	F	S	
	35	FAILURE SUMMARY REPORTS			
		A. EXPERIMENT INSTALLATION AND CHECKOUT		I	S
		B. SPACELAB INTEGRATION	S	I	
		C. CARGO INTEGRATION	F	S	

Table 3.2-16. Summary of Documentation Requirements

	CONCEPT	I				II/VII				III/VI				IV/VIII			V		
	TYPE OF DOCUMENT / CENTER	IC	LS	U	PI	IC	LS	U	PI	IC	LS	U	PI	LS	U	PI	LS	U	PI
OFF LINE	FORMAL	7	1	1	-	8	1	1	-	1	1	7	-	1	8	-	1	7	-
	INFORMAL	2	-	-	-	1	-	-	-	-	-	2	-	-	1	-	-	3	-
	SUPPORT	1	7	5	5	1	8	5	5	6	8	1	5	8	-	5	7	-	4
	TOTALS	10	8	6	5	10	9	6	5	7	9	10	5	9	10	5	8	10	4
		29				30				31				24			22		
IN LINE	FORMAL	16	3	-	-	13	6	-	-	3	6	5	-	6	5	-	3	3	-
	INFORMAL	7	1	6	-	5	3	6	-	-	3	16	-	3	19	-	1	26	-
	SUPPORT	3	9	23	18	7	10	23	18	3	10	10	18	10	7	18	9	3	18
	TOTALS	26	13	29	18	25	19	29	18	6	19	31	18	19	31	18	13	32	18
		86				91				74				68			63		

SHIPPING/TRANSPORTATION

The shipping requirements vary significantly between concepts. Figure 3.2-1 summarizes the flight hardware movements for the processing of the complete Spacelab. The moves of Concepts II, III and IV are equally applicable to the pallet-only configuration concepts (VII, VI and VIII, respectively) if the words "racks/pallet and EM aft bulkhead" are replaced by "pallet, experiment igloos, and PSS equipment."

Individual experiment equipment is shipped twice in Concepts I and II (VII), and once in Concept III (VI). In the other concepts, the experiments are always shipped in the integrated state. Each experiment assembly was considered to be individually packaged and shipped by commercial air freight. Table 3.2-17 illustrates the tabulation of the weights and volumes considered in the shipment of the experiment equipment for one ATL Spacelab payload. Complete lists of experiment equipment for the three baseline ATL payloads are contained in Appendix C.

Air transportation (747 piggyback or C-5A) was selected for all Spacelab, module, rack and pallet assembly, and pallet assembly shipments. Transportation trades presented in Volume II indicated that, in general, road, rail or barge shipment was unacceptable for ATL payloads.

For cost accumulation purposes, the shipping accountability was assigned to the "sender" in preflight operations and to the "recipient" in postflight operations. Table 3.2-18 summarizes the applicable shipments and shipping responsibilities for each concept. The user is accountable for all individual experiment equipment shipments. All shipments in Concepts III, IV, V, VI and VII are accrued to the user except the shipment of the rack/pallet from the launch site to the integration center. The launch site is not accountable for any shipments associated with Spacelab ground processing.

FACILITIES

There is one "facility" that is classified as a mission-unique cost item. This item is the data link for real-time transfer of data during the mission. Good-quality TV (5 MHz bandwidth) was the assumed most stringent ATL requirement.

For a continuing program such as the ATL it is recommended that an Operations Control Center (OCC) be established at the user's site to provide real-time mission support. A definition of the basic requirements for the OCC are presented in Section 5.0, Non-Recurring Requirements. The support service considered in this section is the mission-unique/recurring requirement to relay mission data to the OCC.

During past space programs, relaying of real-time mission data to control centers was primarily accomplished by the use of leased telephone lines. The required bandwidths could be readily accommodated with existing equipment. The only time wideband data was received (TV) was when a spacecraft was within line of sight of a major continental U.S. ground station.

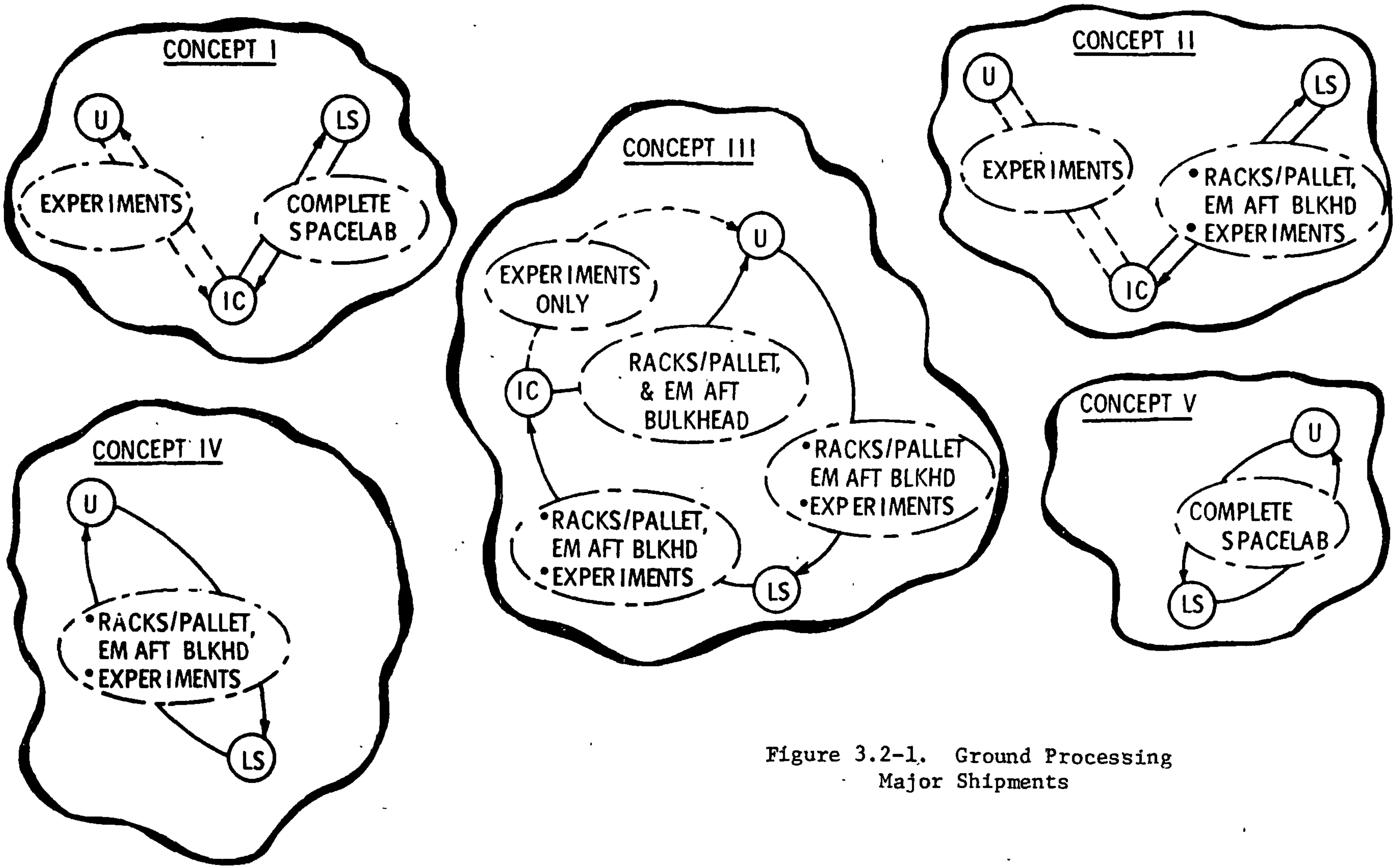

Figure 3.2-1. Ground Processing Major Shipments

Table 3.2-17. Individual Experiment Equipment Shipment

ITEM NO.	NAME	QTY	SIZE (FT) W/DIA	SIZE (FT) H	SIZE (FT) L	VOLUME (CU FT)	WT (EA) (LB)
1	ANALOG TAPE RECORDER	1	1.6	0.9	1.6	2.3	100.
2	RF RECEIVER	1	1.5	0.5	1.25	1.0	15.
3	ANTENNA MOUNT	1	7.0	--	9.0	3.46	*
4	ELECTRONICS	1	2.0	3.0	3.0	18.0	100.
5	ANTENNA	1	6.5	--	0.167	5.53	50.
6	DATA RECORDER	1	1.6	0.9	1.6	2.3	100.
7	BOOM	1	1.0	--	1.0	0.78	20.
8	IR DETECTOR	1	0.4	--	1.5	0.19	5.
9	CRYOGENICS		1.0	--	3.8	3.0	100.
10	TUNEABLE LASER	1	1.5	--	2.3	4.05	50.
11	C/D CONSOLE	1	2.0	3.0	2.5	15.0	60.
12	TELESCOPE, 24-INCH	1	2.0				150.
13	POWER SUPPLY, LASER	1	1.58	1.17	1.5	2.77	100.
14	TV CAMERA	1	0.25	0.5	0.67	0.08	5.
15	STILL CAMERA	1	0.25	0.5	0.5	0.063	50.
16	LASER	1	4.0	4.0	3.0	48.0	260.
17	RETROREFLECTOR	1	1.0	--	1.66	1.3	10.
18	TRACKING INSTRUMENT	1	0.5	1.0	1.0	0.5	20.
19	ELECTRONICS	1	2.0	2.0	3.0	12.0	50.
20	TV MONITOR	1	1.0	1.0	1.5	1.5	25.
21	ANTENNA	4	10.0	--	4.0	314.0	35.
22	POWER SUPPLY	1	1.6	1.0	1.0	1.5	100.
23	ANTENNA MOUNT	1	7.0	--	5.0	192.0	?
24	CAMERA AND INTENSIFIER	2	1.0	2.0	3.84	6.6	305.
25	PHOTOMETER	1	1.0	2.0	1.0	2.0	50.
26	POINTING TELESCOPE	1	0.2	--	1.0	0.031	5.
27	CONTROL/DISPLAY CONSOLE	1	1.58	2.25	2.0	2.1	200.
28	FRAMING CAMERA	1	0.86	2.0	1.9	3.27	65.
29	LENS COVER METER	1					2.
30	MOUNTING PLATE	1	4.0	0.08	4.33	1.39	124.
31	SLIDE AND ACTUATOR	2					75
32	WINDOW	1					160.
33	STILL CAMERA	1	0.5	0.5	0.5	0.125	5.
34	GAS SOURCE	8	1.5	--	3.34	5.9	30.
35	AEROSOL GENERATOR	1	0.5	0.5	1.0	0.25	5.
36	ION GENERATOR	1	0.5	0.5	1.0	0.25	10.
37	WATER VAPOR SOURCE	2	1.0	--	2.0	1.57	20.
38	LIGHT SOURCE	1	0.5	--	3.0	0.59	20.
39	ENVIRONMENTAL CHAMBER	1	1.0	2.0	1.5	3.0	50.
40	MICROSCOPE	1	0.25	--	1.0	0.049	10.
41	INSTRUMENTATION SENSORS						33.
42	CONTROL/DISPLAY PANEL	1	1.7	3.0	2.9	15.0	60.
43	OSCILLOSCOPE	1	1.6	0.6	1.5	1.44	29.
44	COMPUTER	1	1.6	1.0	2.0	3.2	111.
45	DATA PROCESSING EQUIPMENT	1	1.0	1.0	1.0	1.0	10.
46	MOLECULAR BEAM MASS SPECTROMETER	5	0.2	--	0.8	0.024	0.5
47	TAPE RECORDER	1	1.5	1.0	2.5	3.75	130.
48	CONTROL/DISPLAY CONSOLE	1	1.0	1.0	2.0	2.0	50.
49	ION SOURCE	1	0.1	0.1	0.1	0.001	0.1
50	ION COUNTING COLLECTOR SYSTEM	1	0.5	0.5	0.5	0.125	10.
51	MOLECULAR BEAM SUBDIVIDER	1	3.0	--	4.0	28.0	177.
52	MASS FILTER/ION DETECTOR	1					**

NOTES: * WEIGHT INCLUDED IN WEIGHT FOR ITEM NO. 5.
** ITEM PART OF ITEM NO. 46.

Table 3.2-17. Individual Experiment Equipment Shipment (Cont)

ITEM NO.	NAME	QTY	SIZE (FT) W/DIA	H	L	VOLUME (CU FT)	WT (EA) (LB)
53	ELECTRONICS SUPPORT	1	1.0	0.5	0.5	0.25	10.
54	INSTRUMENT CANISTER	1	3.3	--	6.0	50.5	88.
55	GAMMA RAY SPECTROMETER	1	0.9	0.9	1.6	1.3	22.
56	CHARGED PARTICLE SPECTROMETER	1	1.0	2.0	2.0	4.0	80.
57	NEUTRON SPECTROMETER	1	0.5	0.5	3.0	0.75	20.
58	LOGIC SYSTEM	1	0.3	0.3	0.15	0.014	1.
59	ANALOG-TO-DIGITAL CONVERTER	1	1.6	0.25	1.0	4.0	20.
60	SUPERVISOR SYSTEM	1	0.5	0.5	1.0	0.25	5.
61	CONTROL/DISPLAY CONSOLE	1	1.3	2.0	1.3	3.38	50.
62	FILM BADGE	12	0.16	0.15	0.016	0.0004	0.11
63	THERMOLUMINESCENT DOSIMETER	4	0.5	0.4	0.2	0.04	1.
64	ION CHAMBER	4	0.5	0.5	3.0	0.75	30.
65	CRYOGENIC COOLER	1					
66	TUB HOLDER	1	0.43	0.26	0.13	0.014	5.
67	REFRIGERATOR	1	3.0	2.0	1.0	6.0	30.
68	EXPERIMENT CONTAINER	1	0.58	0.42	0.42	0.1	5.
69	INCUBATOR	1	1.69	0.5	2.16	1.82	30.
70	COULTER COUNTER	1	1.69	1.0	2.16	3.65	20.
71	VOLUME SPEC.	1	1.69	0.5	2.16	1.82	15.
72	STORAGE AREA	1	1.69	0.5	2.16	1.82	25.
73	MICROSCOPE/CAMERA	1	0.5	1.75	0.75	0.66	15.
74	ELECTRONICS SENSOR	1	0.67	1.5	0.86	0.84	20.
75	AIR SAMPLE UNIT	2	1.0	1.0	0.5	0.5	15.
76	CONTROL/DISPLAY CONSOLE	1	0.45	0.5	1.0	0.23	10.
77	TIMER	1	0.2	0.2	0.2	0.008	0.5
78	SENSORS	5					2.
79	C/D CONSOLE	1					10.
80	DEPLOYMENT/COLLECTION SYSTEM	5					2.

SUBTOTAL	4,505
CONTAINERS	5,679
WIRE HARNESS	1,000
TOTAL	11,284

Table 3.2-18. Shipment Applicability and Accountability

Shipment \ Concept	I		II & VII		III & VI		IV & VII	V	
Center	U	IC	U	IC	U	IC	U	U	
Experiments U to IC	X		X						PRE-FLIGHT
Racks/Pallets IC/U to LS				X	X		X		PRE-FLIGHT
Spacelab IC/U to LS		X						X	PRE-FLIGHT
Racks/Pallets LS to IC/U				X		X	X		POST-FLIGHT
Spacelab LS to IC/U		X						X	POST-FLIGHT
Experiments IC to U	X		X		X				POST-FLIGHT
Refurb. Racks/Pallet IC to U					X				POST-FLIGHT

During the Shuttle/Spacelab era, relaying of wideband data from almost any orbital position is an assumed operational requirement. The proposed technique for the Shuttle-ground terminal communications link is via a Tracking and Data Relay Satellite (TDRS) system. As currently proposed, this system will consist of two geosynchronous communications relay satellites separated approximately 130 degrees in longitude. Both satellites are within line of sight of a ground terminal at White Sands, New Mexico. This system will provide continuous coverage for spacecraft at an altitude of about 150 nautical miles except for a longitudinal cone of exclusion of about 40 degrees. Virtually continuous coverage is achieved at orbital altitudes of about 500 nautical miles.

The technique for the dissemination of data to the user from the TDRS ground station is currently under study by GSFC. Even if the data were available at GSFC, the per-mission costs to relay the data via leased lines to Langley would be in excess of $100 thousand. The costs to relay the data from White Sands, New Mexico to GSFC would be at least an order of magnitude greater.

An alternative approach that is being evaluated is the use of a geosynchronous commercial communications relay satellite (DOMSAT). Plans are being formulated to position several DOMSAT's over the continental U.S. for general data relay purposes. Current estimates indicate that monthly leases for a transponder channel, which will accommodate all the Shuttle/Spacelab/payload data requirements, will be about $40 thousand.

The DOMSAT approach would consist of relaying mission data from the TDRS ground terminal to the DOMSAT and then re-transmitting the data to various ground terminals. Realistic beam patterns coupled with the transponder bandwidth would permit the dissemination of mission data to any ground station in the continental U.S. Thus, one transponder channel could be shared by the Shuttle and Spacelab operations as well as multiple payload sponsors that are geographically distributed throughout the U.S. Each recipient of the data would, of course, require a DOMSAT ground terminal which is estimated to cost about $250 thousand.

The DOMSAT approach was selected as the baseline real-time mission data relay technique for this study. As the sharing of a transponder channel is neither a prerequisite nor an accepted technique of the DOMSAT approach, it was assumed that the channel would be dedicated to the Spacelab user.

4.0 SUSTAINING REQUIREMENTS

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This section presents the resource requirements for those aspects of integration and checkout that are required to manage and administer the processing of an ATL payload.

It was impractical to estimate the man-months of effort by task for the management/administrative personnel that could be attributed to the integration and checkout of a single Spacelab payload. Therefore, organizational structures were developed to establish the management/administrative functions that contribute to the total ATL program. A sustaining organization was developed for each center (user, IC, LS) involved.

Since sustaining organizations are generally insensitive to flight rate and would have the overall responsibility to manage/direct all the activities associated with the development and implementation of all Spacelab payloads, attributing the total resources of the sustaining organizations to the integration and checkout of an individual payload would be incorrect. Therefore, a pro-ration technique was developed which reflects that portion of the resources that should be attributed to integration and checkout. Estimates of user sustaining resources differentiate between integration and checkout support and the other payload program aspects that managers and staffs will be supporting. The IC and LS pro-rations reflect common management for the processing of up to 24 Spacelab payloads per year. The pro-rated yearly sustaining effort for a two-flight-per-year program varies from 268 to 294 man-months across the candidate concepts.

This section also contains the estimates of the scheduled and non-scheduled maintenance activities associated with the dedicated GSE and facilities required for the integration and checkout of Spacelab payloads. General site maintenance is not included in this sustaining activity.

Two other sustaining operations are discussed. Institutional base support and other administrative activities that pertain to the general management, administration, and maintenance of the processing sites are identified. Such items as machine shops, utilities, office supplies, janitorial services, industrial security, personnel, payroll, and financial are included. Program assessment for these general services are based upon a percentage of the direct costs of that program.

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4.1 PERSONNEL REQUIREMENTS

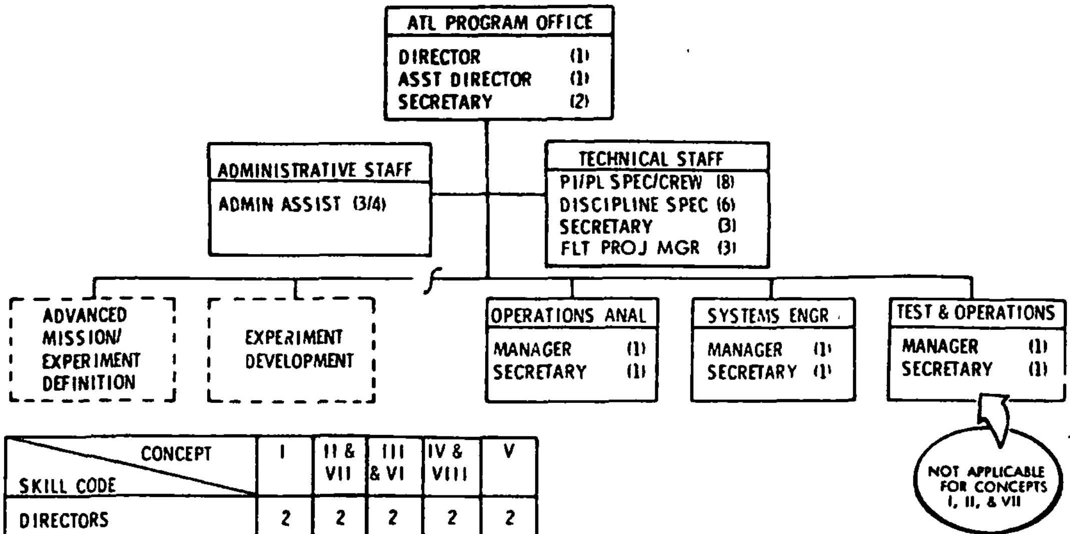
The ATL program personnel that are needed to manage and administer the overall operation are classified as "sustaining." In general, these personnel would be needed for any program regardless of flight rate or whether it is a continuous or one-time program. Therefore, all continuous activities are categorized under 10-00-00 (Program Management) of the WBS and include all managers, office staff, and technical staff.

It is impractical to attempt to estimate the man-months of effort by task for management/administrative personnel that can be accumulated against one facet of complex programs such as the ATL, Spacelab operations, and Shuttle operations. Therefore, an organization chart approach was used to establish the management/administrative functions that contribute to an ATL Spacelab program. An organization for each center for each concept was developed. But the management/administrative organizations will support activities other than just the integration and checkout of two ATL payloads per year. For example, the user organization will include a project/program office that is also involved in advanced mission planning and experiment equipment development; integration center and launch site organizations will direct the processing of numerous Spacelab payloads each year--not just the two baseline ATL payloads. Therefore, a pro-ration criterion was developed to determine that portion of the center organizations that could be attributed to the integration and checkout of two ATL Spacelab payloads per year.

USER CENTER SUSTAINING ORGANIZATION

The user staff requirements for all concepts is shown in Figure 4.1-1. Based upon the processing concepts of two flights per year, and three missions in progress concurrently, there are three flight project managers, three functional managers (one each for operations analysis, systems engineering and test and operations), a payload specialist cadre of eight, and six experiment discipline specialists. Each functional manager and the technical staff have secretaries and an administrative assistant. All managers and staff report to the ATL program director. For Concepts I and II/VII, the test and operations line organization is not required because the associated management functions are provided by the integration center and the launch site. User support to the T&O activities of these concepts will be provided by the systems engineering organization.

As both the PI/payload specialists/crew and the experiment discipline specialists actively participate in advanced mission development, experiment hardware development, and integration and checkout activities, they are considered a staff rather than a line activity.



SKILL CODE \ CONCEPT	I	II & VII	III & VI	IV & VIII	V
DIRECTORS	2	2	2	2	2
MANAGERS	5	5	6	6	6
SENIOR TECH SPECIALISTS	14	14	14	14	14
ADMIN ASSISTANTS	3	3	4	4	4
SECRETARIES	7	7	8	8	8
	31	31	34	34	34

Figure 4.1-1. User Center Sustaining Organization

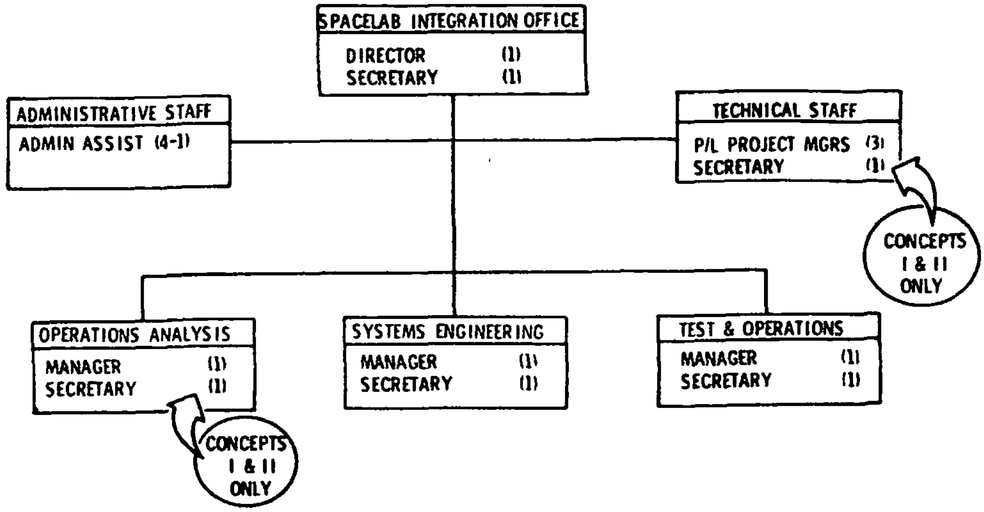
A dedicated flight project manager is assigned for the duration of the integration and checkout process of each ATL mission. The assigned manager must transcend the functional organizations and be cognizant of advanced mission planning and experiment hardware development. The flight project manager is a staff function because, essentially, he is the acting program director on a specific mission during ground processing activities.

The variation in sustaining personnel requirements at the user center for the various concepts is minor. The differences are solely the result of requiring a test and operations organization in some concepts and not in others.

INTEGRATION CENTER SUSTAINING ORGANIZATION

The integration center is involved in Concepts I, II/VII, and III/VI; and the appropriate organizations that relate to the ATL program are shown in Figure 4.1-2. The integration center has line organizations for operations analysis, systems engineering, and test and operations, and a technical and administrative staff--all reporting to the Spacelab integration office director. In Concept III/VI, the operations analysis and the technical staff are not required. These functions are provided solely by the user. The payload project managers (PPM) perform a function at the integration center similar to the flight project managers at the user centers. A PPM is dedicated to an individual mission throughout the entire integration and checkout process, including launch site, mission, and postflight operations.

The applicable integration center organization for Concept III/VI is significantly smaller than for the other concepts because all three levels of Spacelab integration are performed off site. In Concept III/VI, the integration center is primarily involved only in the refurbishment of racks/pallet and the design/fabrication of cables and support structures.

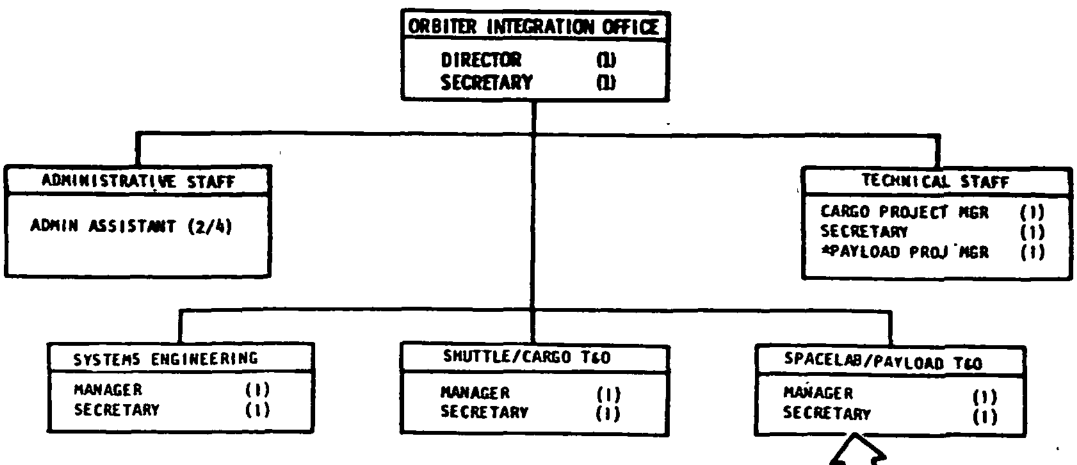


SKILL CODE \ CONCEPT	I	II & VII	III & VI
DIRECTOR	1	1	1
MANAGER	6	6	2
ADMIN ASSISTANT	4	4	1
SECRETARY	5	5	3
	16	16	7

Figure 4.1-2. Integration Center Sustaining Organization

LAUNCH SITE SUSTAINING ORGANIZATION

The launch site sustaining organization of Figure 4.1-3 reflects the variation in the integration levels performed at the launch site in the various



SKILL CODE \ CONCEPT	I	II & VII	III & VIII	IV & VIII	V
DIRECTOR	1	1	1	1	1
MANAGER	3	4	4	4	3
ADMIN ASSISTANT	2	4	4	4	2
SECRETARY	4	5	5	5	4
	10	14	14	14	10

*REPLACES CARGO PROJECT MANAGER IN CONCEPTS II/VII, III/VI AND IV/VIII

Figure 4.1-3. Launch Site Sustaining Organization

processing concepts. It is anticipated that a test and operations organization will be formed that will be dedicated to Level I integration activities. If Level II integration is also performed at the launch site (as in Concepts II/VII, III/VI, and IV/VIII), a separate test and operations organization will be formed. The required complement of administrative assistants and secretaries that support the line organizations vary as a function of the T&O organizations required.

Either a cargo project manager (for Level I integration only) or payload project manager (for Levels I and II integration) is required. The appropriate project manager is responsible for the coordination and accomplishment of all activities associated with the Orbiter payload from arrival at, to departure from, the launch site. It is believed that a more efficient operation can be achieved if continuity of launch site project management is maintained throughout launch site processing, rather than changing management between Level II and Level I integration. Thus, the variation in launch site sustaining personnel requirements is solely a function of the levels of integration performed at that site.

PRO-RATION OF SUSTAINING MANPOWER

In general, the sustaining organizations presented above are insensitive to flight rate and would manage/direct the activities of all Spacelabs being processed under their cognizance. Therefore, charging the ATL program for the total costs of the sustaining organizations would be inappropriate. A pro-ration was developed which reflects that portion of the organizations that would be chargeable to ATL. Also, the costs accumulated in this study are solely for the integration and checkout phase of the ATL program. Pro-rations of user sustaining costs were identified to differentiate between the integration and checkout support and support to other facets of the ATL program. The pro-rations are summarized in Table 4.1-1.

Table 4.1-1. Selective Proportion of Supporting Personnel Costs

	APPLICABLE CHARGES (%)	RATIONALE
USER CENTER		
PROGRAM OFFICE	33	DIRECTS INTEGRATION, ADVANCED MISSION PLANNING, AND EXPERIMENT DEVELOPMENT
ADMINISTRATIVE STAFF	33	SUPPORTS ALL ACTIVITIES OF PROGRAM OFFICE
PI/PL SPECIALIST/CREW	33	DIRECTLY CONTRIBUTES TO ADVANCED MISSIONS AND EXPERIMENT DEVELOPMENT
DISCIPLINE SPECIALISTS	50	PRIMARY LIAISON BETWEEN EXPERIMENT DEVELOPMENT AND INTEGRATION
INTEGRATION CENTER		
ALL EXCEPT PL PROJECT MANAGERS	8	ORGANIZATION SUPPORTS UP TO 24 SPACELAB FLIGHTS PER YEAR
LAUNCH SITE		
ALL EXCEPT TECHNICAL STAFF	8	ORGANIZATION SUPPORTS UP TO 24 SPACELAB FLIGHTS PER YEAR
PAYLOAD PROJECT MANAGERS	33	EACH PL/SM/EM AT LS 2 MONTHS
CARGO PROJECT MANAGERS	25	EACH SPACELAB AT LS 1.5 MONTHS

User Center

The program office, administrative staff and PI/payload specialist/crew personnel support all three major activities of the ATL program. Therefore, only one third of the associated costs are attributed to the integration and checkout activities. The primary function of the experiment discipline specialists is to provide the technical liaison between the experiment development activity and the integration and checkout activities. It is believed that the specialist support will be equally divided between the two aspects of the ATL program. The flight project managers are dedicated to individual missions and therefore are directly attributed to the integration and checkout activity. The line organizations are assigned full time to integration and checkout.

Integration Center

Current Spacelab program planning indicates that an average of 24 Spacelabs (complete Spacelab and pallet-only) will be flown each year by the mid-1980's. If only two of these are ATL Spacelabs, then only 1/12 of the integration center sustaining organization is attributable to the ATL program. The one exception is the payload project manager, who is dedicated to an ATL payload for the duration of the integration and checkout activities. His time is directly chargeable to the ATL.

Launch Site

The criteria for the pro-ration of launch site sustaining organization charges are the same as for the integration center. One twelfth of the sustaining organization, with the exception of the technical staff, is attributable to the ATL. In Concepts I and V, the ATL Spacelab is "at" the launch site for approximately 1.5 months including Level I integration, seven-day mission, and post-landing operations. Thus, a cargo project manager will support eight flights per year. For a two-flights-per-year ATL program, one fourth of a cargo project manager's time is attributable to the ATL. In the other processing concepts, Level II integration is also performed at the launch site. The additional tasks increase the involvement time of the payload project manager (as compared to the cargo project manager) to about two months. Ideally, this manager can support six flights per year, or one third of his time would be dedicated to a two-flight-per-year ATL program.

Summary

Based upon the baseline two-flight-per-year ATL program used in this study, the pro-rations described above were applied to the sustaning organizations. As the management/administrative staffing requirements are relatively insensitive to the yearly flight rate, the man-months of sustaining effort were derived on a yearly basis.

Table 4.1-2 summarizes the requirements by concept and by center. The variation in the total effort across the concepts is only 26 man-months. Although this variation is a factor to be considered in concept evaluations, it is not considered to be a discriminator in the selection or applicability

of a concept. The requirements of the user organization only vary about 10 percent across the concepts, but account for approximately 80 percent of the total for each concept. A modified pro-ration of the sustaining organization support at the integration center and launch site could reduce the differences between concepts to a negligible value.

Table 4.1-2. Pro-Rated Yearly Sustaining Requirements
Two Flights Per Year
(Man-Months)

SKILL CODE / CONCEPT	I			II & VII			III & VI			IV & VIII		V	
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	LS	U	LS
DIRECTORS	8	1	1	8	1	1	8	1	1	8	1	8	1
MANAGERS	60	39	5	60	39	7	72	2	7	72	7	72	5
TECH SPECIALIST	104	-	-	104	-	-	104	-	-	104	-	104	-
ADMINISTRATORS	12	4	2	12	4	4	16	1	4	16	4	16	2
SECRETARIES	44	5	4	44	5	5	56	3	5	56	5	56	4
TOTALS	228	49	12	228	49	17	256	7	17	256	17	256	12
	289			294			280			273		268	

4.2 OPERATIONS REQUIREMENTS

In addition to sustaining personnel requirements, there are scheduled and non-scheduled maintenance activities associated with GSE and facilities uniquely used for the integration and checkout of Spacelab payloads. Also, a pro-ration of institutional base and other administrative functions can be attributed to integration and checkout activities at each site involved. These items are identified in this section.

GSE AND FACILITY MAINTENANCE

In addition to the capital investment of the initial procurement of Spacelab-related GSE and facilities, a continuing or sustaining maintenance/refurbishment effort is required. Simulators, transporters, test stands, consoles, cranes, enclosures, air purifiers, and other unique provisions for Spacelab processing must be periodically repaired, calibrated, serviced, etc.

Tables 4.2-1 and 4.2-2 present the manpower estimates for each center for each concept for GSE and facilities maintenance, respectively. Pro-ration of efforts is not applied in the case of maintenance operation because it is assumed to be a linear function of usage. The estimates are based upon a flight rate of two per year. The personnel are considered to be part of the general maintenance staff of the center. A technician-mechanic skill code was assumed.

Table 4.2-1. Sustaining GSE Maintenance Requirements
(Man-Months

Center \ Concept	I	II & VII	III & VI	IV & VIII	V
User	-	-	5	5	6.0
IC	6.0	5	1	-	-
LS	0.5	1	1	1	0.5
Totals	6.5	6	7	6	6.5

Table 4.2-2. Sustaining Facility Maintenance Requirements
(Man-Months)

Center \ Concept	I	II & VII	III & VI	IV & VIII	V
User	-	-	4	4	4.0
IC	4.0	4	1	-	-
LS	0.5	1	1	1	0.5
Totals	4.5	5	6	5	4.5

INSTITUTIONAL BASE

Although institutional base support is not a direct program charge, a percentage of the cost of running a site should be assessed to each program. Included in base support are such services as general-purpose labor, machine shops, all utilities, data processing center, general office buildings, office supplies, and general maintenance. Generally, the assessment for these services are based upon a percentage of the total direct costs of a program at a site.

OTHER ADMINISTRATIVE COSTS

In addition to institutional base services, there are administrative support functions such as industrial security and safety, travel, traffic control, material handling, personnel, payroll, and financial. The assessment for these sustaining functions were also based upon a percentage of the direct program charges at each site.

5.0 NON-RECURRING REQUIREMENTS

5.0 NON-RECURRING REQUIREMENTS

This section presents a description of the non-recurring resources required to initiate each of the candidate processing concepts. The non-recurring resource data are subdivided into three principal areas: (1) non-recurring support functions, (2) GSE requirements, and (3) facilities requirements.

The non-recurring support functions are those activities required to implement the user-unique requirements into the overall operational Spacelab program. The majority of this effort is an expansion and adaptation of the data package describing the constraints and accommodations of the Spacelab program, which will be derived during Spacelab hardware and operations development, to accommodate the procedures and applications of an individual user. Only those support functions that pertain to the definition of GSE and facility requirements and site activation vary significantly across the candidate concepts.

In every program of the anticipated complexity and size of the ATL Spacelab, there are major GSE requirements that heavily influence the selection of a preferred approach. Section 5.2 describes the GSE requirements for all eight candidate processing concepts. A definition of each item of checkout, auxiliary, servicing, and handling equipment and a brief description of the intended use of the GSE is provided. Anticipated ESRO/ERNO and NASA supplied GSE are identified.

Comparisons between GSE requirements for complete Spacelab processing concepts and also pallet-only processing concepts are presented. A significant difference between processing concepts for a given Spacelab configuration results from the involvement of three centers in one concept versus the involvement of only two centers in the other concept. With the exception of two items of GSE (payload specialist station simulator at the Level III integration site, and systems igloo handling equipment at the Level II integration site), the complement of GSE to process a complete Spacelab configuration can also accommodate the processing of a pallet-only configuration.

The facility requirements to implement the eight processing concepts are discussed in Section 5.3. Generic building/space requirements were derived for each concept. Comparison of these generic requirements with facilities at Langley (user), MSFC (integration center), and KSC (launch site) indicated that all requirements can be fulfilled by modifications to existing buildings at these centers. Planned building modifications at MSFC (Building 4755) and KSC (MSOB) reflect accommodations for processing of up to 24 Spacelab payloads per year. Building 1293A at Langley could be modified to accommodate ATL Spacelab processing requirements. An area of approximately 2400 ft^2 is also required at Langley for an Operations Control Center (OCC) for real-time mission support. Space in an existing building will suffice; a new building is not required.

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5.1 NON-RECURRING SUPPORT FUNCTIONS

The non-recurring functions that support integration and checkout are those activities required to generate the controlling documentation to guide and implement the Spacelab program. However, it must be recognized that not all these non-recurring support function activities are attributable to a user program such as the ATL. There are three distinct categories of support function development: (1) Spacelab manufacture, (2) Spacelab operations development, and (3) user implementation. Only the third category is chargeable to the integration and checkout activities of the ATL program. Each category of support function is discussed below.

SPACELAB MANUFACTURE

As part of the development of the Spacelab by ESRO/ERNO, a rather comprehensive data pack is being generated. This data pack will provide the basic guidelines, constraints, and operations potential for the Spacelab. A generalized list of the contents of the ESRO/ERNO data pack that is directly applicable to integration and checkout activities is presented below.

1. Control and Data Management System Software
   - Operating System
   - Executive
   - Subsystem application modules
   - Subsystem checkout and performance modules
2. Simulation Software
   - Subsystem programming language
   - Assembler/compiler
   - Test and validation
   - Diagnostic
3. Drawings, Schematics, Load Analyses/Profiles
4. Maintenance Schedules
5. Fault Isolation Procedures
6. Payload Accommodations Document
   - Imposed environment
   - Utilities
   - Safety
   - Reliability
   - Common payload support equipment

This data pack will enable the NASA (MSFC) to initiate the development of Spacelab operations for general usage. The data pack is considered to be part of the purchase of the Spacelab and will be delivered with the first Spacelab.

SPACELAB OPERATIONS DEVELOPMENT

As part of the development of a Space Transportation System, the NASA, and specifically MSFC, will generate a Spacelab operational plan. The task will result in the expansion and refinement of the basic data pack received from ESRO/ERNO to facilitate the use of the Spacelab by many diverse users.

Parallel operations development will be conducted by JSC and KSC for the Shuttle. Included in these activities are definitization of integration and checkout of the Spacelab/Orbiter including interface identification, assembly procedures, tests and operations, flight and post-flight operations, and performance characteristics and constraints that relate specifically to the Spacelab user. MSFC as lead center for Spacelab, and JSC/KSC as lead centers for Orbiter operations development, will have the primary roles in the derivation of the Spacelab operations plan. Potential users will, of course, participate in the operations development phase but it is impractical to define specific tasks for the users.

The definitized documents that are anticipated for general Spacelab user guidance, which MSFC will produce, include the following:

1. Logistics plans and specifications
2. Payload design criteria
3. Interface control documentation
4. Reliability criteria
5. Safety criteria
6. Spacelab/STS operating procedures
7. Turnaround/refurbishment plans
8. Assembly and checkout procedures
9. Software development and verification procedures
10. Configuration control procedures

Regardless of the Spacelab processing concept used during the operational era, these basic Spacelab user guideline/constraint documents will be generated. Table 5.1-1 presents an estimate of the man-months of effort, within the WBS format, for the generation of the non-recurring support function data pack that will be available to all potential users. Also, estimates for GSE/facility requirements definition and activation are included. The anticipated efforts of KSC and JSC in the development of the data pack are not broken out; they are merely summed under the "launch site" heading. This significant effort to initiate Spacelab operations is not attributable to a Spacelab user. It is considered to be in the same general-use category of agency developments such as the TDRS/STDN, Launch Processing System, C-5A/747 Transporter, Space Shuttle, and Spacelab flight hardware.

Table 5.1-1. Non-Recurring Documentation Man-Months

WBS Task		Center IC	Center LS
20.10.10	Logistics Plans	20	15
50.10.10.40	Experiment Design Criteria	50	5
50.10.40	GSE/Facilities Requirements	110	110
50.20.10.10	Operating Instructions	130	30
50.20.10.20	Equipment Specifications	180	20
50.20.20.10	Layout and Installation	150	20
50.20.20.20	Interface Hardware	150	20
50.20.20.30	Turnaround and Refurbishment Plan	10	10
50.20.30	ICD's	40	50
50.30.20.40	Repair and Refurbishment Software	10	10
50.30.10	Data and Software Requirements	50	5
50.30.20	Software Development & Verification	100	20
50.40.10	Reliability Specifications	10	5
50.50.10	Safety Standards	20	10
75.20	Site Activation	60	60
Total		1090	390
		1480	

The data in Table 5.1-1 have been presented for comparison purposes with that of the user-unique non-recurring manpower requirements (Table 5.1-2). The magnitude of these IC and LS non-recurring manpower estimates to develop an operational capability are approximately seven times the effort required to tailor the general operation plans and procedures for a user's unique requirements and/or capabilities.

USER IMPLEMENTATION

Because of the inherent flexibility of the Spacelab, and the large number of potential users with diverse application requirements, it is impractical to assume that the operational data pack produced by MSFC will accommodate all users. For example, Langley will be required to develop a custom logistics plan, repair/refurbishment/disposition procedures, and GSE and facility requirements that are commensurate with the physical and procedural constraints of the center and reflect a two-flight-per-year schedule. Experiment design criteria and reliability and safety standards could be unique: cost analyses could indicate preferred approaches (e.g., software versus manual implementation of controls); reliability may be less stringent; safety standards must reflect the man-machine interfaces peculiar to experimental operations involving such items as fluids and test specimens. Implementation of interface control procedures, although not a unique activity, would also be a delta effort for the ATL program.

A customizing or tailoring of the general operations plan for each user was assumed. This effort is considered user-unique and is directly attributable to the integration and checkout activities analyzed in this study.

This customizing is concept-dependent. Estimates for each concept for each task (in the WBS format) are presented in Table 5.1-2. The differences between concepts are almost entirely attributable to GSE and facility definition and activation at the user's site.

Table 5.1-2. User-Unique Non-Recurring Manpower Requirements

WBS TASK \ CONCEPT / CENTER	I			II & VII			III & VI			IV & VII		V	
	U	IC	LS	U	IC	LS	U	IC	LS	U	LS	U	LS
20.10.10 LOGISTIC PLANS		20	3		20	3	20	6	3	20	3	20	3
50.10.10.40 EXPERIMENT DESIGN CRITERIA		50			50		50			50		50	
50.10.40 GSE/FACILITY REQUIREMENTS							50			50		90	
50.20.10.10 OPERATING INSTRUCTIONS		24			24		20	5		25		25	
50.20.10.20 EQUIPMENT SPECIFICATIONS		24			24		10	14		24		24	
50.20.20.30 TURNAROUND REFURBISHMENT PLAN	10	10		10	10	4	10	5	4	10	4	14	
50.20.30 ICD'S	10	10	10	10	10	10	20		10	20	10	20	10
50.30.20.40 REPAIR & REFURBISHMENT SOFTWARE		4			4		10	4		14		14	
50.30.20.50 TEST/VALIDATION SOFTWARE		8			8		8			8		8	
50.40.10 RELIABILITY SPECIFICATIONS	5	5		5	5		5	5		5		5	
50.50.10 SAFETY STANDARDS	10	10		10	10		10			10		10	
75.20 SITE ACTIVATION							40			40		100	
TOTAL	35	165	13	35	165	17	253	39	17	276	17	380	13
	213			217			309			293		393	

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5.2 GROUND SUPPORT EQUIPMENT

The requirements for ground support equipment (GSE), developed for the five complete Spacelab and three pallet-only checkout concepts were predicated upon minimal utilization of automatic ground support checkout equipment. The checkout flows reflect a dependency upon basic support GSE (e.g., power, coolant flow, and servicing units), coupled with maximum usage of on-board systems. For test activities, where utilization of actual flight elements is impractical or impossible, simulators such as the support module, igloo, or Orbiter interface simulator are used.

GSE REQUIREMENTS DEFINITION

Based upon the activity data sheets (Appendix D) that were developed for each test and operation for each of the eight processing concepts, the GSE required to accomplish the three levels of Spacelab integration was defined.

Equipment Requirements

Each test and operation was evaluated to determine the type and quanity of GSE that was required. Where appropriate, caravaning of GSE from site to site was identified. The supplier of the GSE was also identified. Current planning by NASA/ESRO indicates that a significant quantity of GSE will be provided with the Spacelab. Non-ESRO-provided GSE was classified as NASA-supplied.

Tables 5.2-1 through 5.2-5 summarize the GSE requirements. The tests and operations that require each item are identified. The quantity required at each site, as well as the recommended number of spares, are also identified. GSE requirements for Concepts I and V are the same; only the cognizant center changes (integration center in Concept I--user center in Concept V). Similar relationships exist for Concepts II and IV, and VII and VIII.

Equipment Classification

Because of the different cost factors and procurement lead times involved, it was advantageous to classify the GSE into four categories: checkout, handling, auxiliary, and servicing. All subsequent GSE data are grouped in these categories. The generalized definitions for the four categories are as follows:

1. Checkout. Equipment that has a unique application to the test in progress, providing inputs or outputs that are necessary for an assessment of system performance.

Table 5.2-1. Concepts I and V Ground Support Equipment Requirements

CONCEPT I & V				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
IC/U	IC/U	IC/U	IC/U	IC/U

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/PALLET SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC (I)/U (V)	ACTIVE LS (II & V)	ACTIVE	SPARES IC(I)/U(V)	SPARES LS (II & V)
	ESRO-SUPPLIED																											
	HANDLING																											
	Interior Access Kit																											
1	- Contingency Entry Kit Vert.												X											-	1		-	-
2	- Horizontal Entry Kit											X												-	1		-	-
	EXTERIOR ACCESS KIT																											
3	- Scaffolding (ESRO Comm. type)							X	X	X	X	X					X							2	1		-	-
4	- Auxiliary Floor Panels - Pallets		X		X																			1	-		-	-
	SLING ASSEMBLY KITS																											
5	- End Cone Sling Set		X																	X				1	-		-	-
6	- Vertical Sling Kit												X											-	1		-	-
7	- Horizontal Sling Kit								X	X	X	X			X		X							1	1		-	-
8	- Igloo Handling Kit		NOT APPLICABLE																									
9	- Upper Handling Cage-Module								X	X	X	X			X		X							1	1		-	-
10	- Lower Handling Cage-Module								X	X	X	X			X		X							1	1		-	-
11	- Upper Handling Cage-Pallet								X	X	X	X			X		X							1	1		-	-
12	- Handling Platform-Pallet								X	X	X	X			X		X							1	1		-	-
13	- Utility Bridge Handling Kit		X																	X				1	-		-	-
	STORAGE FIXTURES																											
14	- EM Storage Fixture																					X		1	-		-	-
15	- SM Storage Fixture																					X		1	-		-	-
16	- Pallet Storage Fixture																			X				1	-		-	-
17	- Rack/Rack Set/Floor Assy																			X				1	-		-	-

Table 5.2-1. Concepts I and V Ground Support Equipment Requirements (Cont)

CONCEPT I & V				
OWNER				INTEG. SITE
SM	EM	P	EXPMT EQUIP	SL
IC/U	IC/U	IC/U	IC/U	IC/U

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/ PALLET SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC(I)/U(V)	ACTIVE LS (I & V)	SPARES IC(I)/U(V)	SPARES LS (I & V)
	ESRO-SUPPLIED																										
	HANDLING (Continued)																										
18	Main Assembly Stand		X		X			X	X		X							X						2	1	-	-
19	Alignment Work Stand							X										X						1	-	-	-
20	Aft End Cone Stand		X																	X				1	-	-	-
21	End Cone Support		X		X			X										X		X				1	-	-	-
22	Rack and Floor Rail Set							X										X						1	-	-	-
	Transporters																										
23	- Transporter Platform-Module									X	X	X			X		X	X				X		1*	-	-	-
24	- Transporter Platform-End Cove		X																	X				1	-	-	-
25	- Transporter Platform-Rack/ Rack Set/Floor		X							X	X	X			X		X	X						1	-	-	-
26	- Transport Trailer		X							X	X	X			X		X	X		X		X		1	1	-	-
	CHECKOUT																										
27	Data Processing Equipment			X	X				X															1	-	1	-
28	Ground Power Supply			X	X				X															1	-	1	-
29	Electrical Power Test Set			X	X				X															1	-	-	-
	Simulators																										
30	- Support Module Simulator			X	X																			1	-	1	-
31	- Orbiter I/F Simulator								X															1	-	1	-
32	Control & Data Acquisition Cons.			X	X				X															1	-	1	-
	Cable Kits																										
33	- Ground Test Remote Site Cable Kit				X				X			X												1	1	-	-
34	- Launch Support (Vertical) Cable Kit												X											-	1	-	-

*Caravaned item.

Table 5.2-1. Concepts I and V Ground Support Equipment Requirements (Cont)

CONCEPT I & V				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
IC/U	IC/U	IC/U	IC/U	IC/U

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/PALLET SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC (I/U (V)	ACTIVE LS (I & V)	SPARES IC (I/U (V)	SPARES LS (I & V)
	ESRO-SUPPLIED																										
	CHECKOUT (Continued)																										
	Cable Kits (Continued)																										
35	- Subsystem Test Cable Kit								X															1	-	-	-
36	- Experiment Test Cable Kit				X																			1	-	-	-
37	- Prelaunch Servicing Cable Kit											X	X											-	2	-	-
38	- Recovery Cable Kit														X									-	1	-	-
39	- Electrical System Test Cable Kit								X			X												1	1	-	-
40	- GSE/Facility Cable Kit				X				X			X												1	1	-	-
41	Memory Load & Verify Unit			X	X				X															1	-	1	-
42	ECLSS Test Unit								X			X	X											1	-	-	-
43	Continuity Test Equipment		X	X	X			X	X			X												1	1	-	-
44	SL Module Universal Seal Test Console								X			X	X											1	1	-	1
	AUXILIARY																										
45	Lighting Kit		X		X			X	X			X	X					X				X		2	1	-	-
46	Ground Air Cooling Unit (Equipment)			X	X				X															1	-	1	-
	Environmental Control Kit - Transport/Storage																										
47	- Environmental Soft Cover-Mod.									X	X	X			X		X							1*	-	-	-
48	- Environmental Soft Cover-Rack/Pallet									X	X	X			X		X							1	-	-	-
49	-Environmental Soft Cover-Utility Bridge									X	X	X			X		X							1	-	-	-

*Caravaned item.

Table 5.2-1. Concepts I and V Ground Support Equipment Requirements (Cont)

CONCEPT I & V				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
IC/U	IC/U	IC/U	IC/U	IC/U

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/ PALLET SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC (I)/U (V)	ACTIVE LS (I & V)	SPARES IC(I)/U (V)	SPARES LS (I & V)
	ESRO-SUPPLIED																										
	AUXILIARY (Continued)																										
	Environment Control Kit - Transport/Storage (Continued)																										
50	Environmental Soft Cover -Pallet									X	X	X			X		X							1	-	-	-
51	Environmental Soft Cover-End Cone									X	X	X			X		X							1	-	-	-
	Protective Cover Kits																										
52	- Module Transporter-Protective Cover																							1	-	-	-
53	- End Cone Transporter-Protective Cover		Anytime transporters are not in use, these protective covers will be required.																					1	-	-	-
54	- Racks/Rack Set/Floor Assy, Transporter-PC																							1	-	-	-
55	- Transporter Trailer-Protective Cover																							1	1	-	-
56	Transducer/Gage Calibration Kit		X		X			X				X	X							X		X		1	1	1	-
57	Interior Protective Devices							X	X		X	X	X				X	X						1*		-	-
58	SM/EM Hatch/Seal Protective Covers							X														X		1	-	-	-
59	SM Hatch Cover and Seal							X	X	X	X													1	-	-	-
	SERVICING																										
60	Ground Servicing & Cooling Unit			X	X				X			X								X		X		1	1	1	-
61	GO_2 Transfer & Servicing Unit								X			X	X		X									1	1	-	1
62	GN_2 Transfer & Servicing Unit								X			X	X		X									1	1	-	1
63	Freon Transfer & Servicing Unit			X	X				X			X								X		X		1	1	1	-
64	Vacuum Servicing Unit				X				X			X			X					X		X		1	1	-	-
65	O_2/N_2 Pressure Unit								X			X	X		X									1	1	-	-

*Caravaned item.

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Table 5.2-1. Concepts I and V Ground Support Equipment Requirements (Cont)

CONCEPT I & V				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
IC/U	IC/U	IC/U	IC/U	IC/U

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS.	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/PALLET SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC (I)/U (V)	ACTIVE LS (I & V)	SPARES IC (I)/U (V)	SPARES LS (I & V)
	NASA-SUPPLIED																										
	HANDLING																										
1	Weight and Balance Sling								X															1	-	-	-
2	Alignment Kit		X		X			X				X												1	1	1	1
3	Cargo Lift Trailer									X	X						X							1	1	-	-
4	Air Transport Tie Down Kit (C-5A)									X	X						X							1	-	-	-
5	Mobile Hoist/Sling		X																	X		X		1	-	-	-
6	Small Equipment Transport Carts	X	X	X	X	X			X			X			X					X		X		5	5	-	-
7	Space Lab Shipping Canister (747)									X	X	X			X		X							1*	-	-	-
8	Spacelab Shipping Canister Sling									X	X	X			X		X							1*	-	-	-
	CHECKOUT																										
9	EMI Test Equipment				X				X			X												1	1	-	-
10	Electrical Load Banks											X												-	1	-	-
11	Optical Measurement Unit								X															1	-	-	-
	AUXILIARY																										
12	Battery Activity Unit											X												-	1	-	1
13	Clean Enclosure (10K Portable)										X	X												-	2	-	-
	Weight and Balance Kit																										
14	-Weight & Balance Measuring Equipment								X															1	-	1	-
15	Structural Repair Kit		X		X				X		X	X	X							X		X		1	1	-	-
16	Cleaning Kit		X		X			X	X	X	X	X	X							X		X		1	1	-	-
17	Transportation Instrumentation									X							X							1*	-	-	-

*Caravaned item.

Table 5.2-1. Concepts I and V Ground Support Equipment Requirements (Cont)

CONCEPT I & V				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
IC/U	IC/U	IC/U	IC/U	IC/U

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS.	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/ PALLET SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC (I)/U (V)	ACTIVE LS (I & V)	SPARES IC (I)/U (V)	SPARES LS (I & V)
	NASA-SUPPLIED																										
	AUXILIARY (Continued)																										
18	Flow Rate Test Set			X	X				X											X		X		1	-	-	-
19	Leak Detector/MSS Spectrometer			X	X				X			X	X		X					X		X		1	1	1	1
20	X-Ray Unit		X						X			X								X		X		1		-	-
21	Installation Too Kit (Gask-O-Seal)		X					X												X		X		1	-	-	-
22	SL Safing Equipment Set														X									-	1	-	-
23	General Purpose Lab Equip. Set			X	X			X	X		X	X	X							X		X		1	1	-	-
24	Ground Air Conditioning Unit (Personnel)								X		X	X	X		X							X		1	1	1	1
	SERVICING																										
25	Trace Gas Servicer			X	X				X			X	X		X					X		X		1	1	-	-
26	Cryogenic Servicing Unit												X											-	1	-	-
27	Hypergolic Servicing Units												X		X									-	1	-	-

Table 5.2-2. Concepts II and IV Ground Support Equipment Requirements

CONCEPT II & IV				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
LS/LS	LS/LS	IC/U	IC/U	LS/LS

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/PALLET SHIPMENT	ACTIVE IC(II)/U (IV)	ACTIVE LS (II & IV)	SPARES IC(II)/U(IV)	SPARES LS (II & IV)
	ESRO-SUPPLIED																										
	HANDLING																										
	Interior Access Kit																										
1	- Contingency Entry Kit Vertical												X											-	1	-	-
2	- Horizontal Entry Kit											X												-	1		
	Exterior Access Kit																										
3	- Scaffolding (ESRO Commercial Type)						X	X	X			X				X			X					1	2	-	-
4	- Auxiliary Floor Panels - Pallets		X		X																			1	-	-	-
	Sling Assembly Kits																										
5	- End Cone Sling Set		X																	X				1	-	-	-
6	- Vertical Sling Kit												X											-	1	-	-
7	- Horizontal Sling Kit						X		X			X			X	X			X					1	1	-	-
8	- Igloo Handling Kit		NOT APPLICABLE																								
9	- Upper Handling Cage-Module								X			X			X	X								-	1	-	-
10	- Lower Handling Cage-Module								X			X			X	X								-	1	-	-
11	- Upper Handling Cage-Pallet						X		X			X			X	X			X					1	1	-	-
12	- Handling Platform - Pallet						X		X			X			X	X			X					1	1	-	-
13	- Utility Bridge Handling Kit		X																	X				1	-	-	-
	Storage Fixtures																										
14	- EM Storage Fixture																					X		-	1	-	-
15	- SM Storage Fixture																					X		-	1	-	-
16	- Pallet Storage Fixture																		X					1	-	-	-
17	- Rack/Rack Set/Floor Assy.																		X					1	-	-	-
18	Main Assembly Stand		X		X			X	X							X		X						1	2	-	-
19	Alignment Work Stand							X										X						-	1	-	-
20	Aft End Cone Stand		X																	X				1	-	-	-
21	End Cone Support		X		X		X	X										X	X	X				1	-	-	-
22	Rack and Floor Rack Set							X										X						-	1	-	-

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Table 5.2-2. Concepts II and IV Ground Support Equipment Requirements (Cont)

CONCEPT II & IV				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
LS/LS	LS/LS	IC/U	IC/U	LS/LS

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/PALLET SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC (II)/U (IV)	ACTIVE LS (II & IV)	SPARES IC (II)/U (IV)	SPARES LS (II & IV)
	ESRO-SUPPLIED																										
	HANDLING (Cont.)																										
	Transporters																										
23	- Transporter Platform-Module											X			X	X		X				X		-	1	-	-
24	- Transporter Platform - End Cone		X				X											X	X	X				1*	-	-	-
25	- Transporter Platform-Rack/Rack Set/Floor						X					X			X	X		X	X	X				1*		-	-
26	- Transport Trailer						X					X			X	X		X	X	X		X		1	1	-	-
	CHECKOUT																										
27	Data Processing Equipment			X	X				X															1	1	1	1
28	Ground Power Supply			X	X				X															1	1	1	1
29	Electrical Power Test Set			X	X				X															1	1	-	-
	Simulators																										
30	- Support Module Simulator			X	X																			1	-	1	-
31	- Orbiter I/F Simulator								X															-	1	-	1
32	Control & Data Acquisition Cont.			X	X				X															1	1	1	1
	Cable Kits																										
33	- Ground Test Remote Site Cable Kit				X				X			X												1	1	-	-
34	- Launch Support (Vertical) Cable Kit												X											-	1	-	-
35	- Subsystem Test Cable Kit								X															-	1	-	-
36	- Experiment Test Cable Kit				X																			1	-	-	-
37	- Prelaunch Servicing Cable Kit											X	X											-	2	-	-
38	- Recovery Cable Kit														X									-	1	-	-
39	- Electrical System Test Cable Kit								X			X												-	1	-	-
40	- GSE/Facility Cable Kit				X				X			X												1	1	-	-

*Caravaned item.

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Table 5.2-2. Concepts II and IV Ground Support Equipment Requirements (Cont)

CONCEPT II & IV				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
LS/LS	LS/LS	IC/U	IC/U	LS/LS

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/PALLET SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC (II)/U (IV)	ACTIVE LS (II & IV)	SPARES IC (II)/U (IV)	SPARES LS (II & IV)
	ESRO-SUPPLIED																										
	CHECKOUT (Cont.)																										
41	Memory Loads & Verify Unit			X	X				X															1	1	1	1
42	ECLSS Test Unit								X			X	X											-	1	-	-
43	Continuity Test Equipment		X	X	X			X	X			X												1	1	-	-
44	SL Module Universal Seal Test Console								X			X	X											-	1	-	1
	AUXILIARY																										
45	Lighting Kit		X		X			X	X			X	X					X				X		1	2	-	-
46	Ground Air Cooling Unit (Equipmt)			X	X				X															1	1	1	1
	Environmental Control Kit-Transport/Storage																										
47	- Environmental Soft Cover-Mod.											X			X									-	1	-	-
48	- Environmental Soft Cover-Rack Pallet						X					X			X				X					1*		-	-
49	- Environmental Soft Cover - Utility Bridge						X					X			X				X					1			
50	- Environmental Soft Cover - Pallet						X					X			X				X					1		-	-
51	- Environmental Soft Cover - End Cone						X					X			X				X					1		-	-
	Protective Cover Kits																										
52	- Module Transporter - Protective Cover																								1	-	-
53	- End Cone Transporter - Protective Cover		Any time transporters are not in use, these protective covers will be used.																					1	-	-	-
54	- Racks/Rack Set/Floor Assy, Transporter - PC																							1	-	-	-
55	- Transporter Trailer - Protective Cover																							1	1	-	-

*Caravaned item.

Table 5.2-2. Concepts II and IV Ground Support Equipment Requirements (Cont)

CONCEPT II & IV				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
LS/LS	LS/LS	IC/U	IC/U	LS/LS

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/PALLET SHIPMENT	QUANTITY REQUIREMENTS: ACTIVE IC (II)/U (IV)	ACTIVE LS (II & IV)	ACTIVE	SPARES IC (II)/U (IV)	SPARES LS (II & IV)
	ESRO-SUPPLIED																											
	AUXILIARY (Continued)																											
56	Transducer/Cage Calibration Kit		X		X				X			X	X							X		X		1	1		1	-
57	Interior Protective Devices							X	X			X	X			X		X						1	-		-	-
58	SM/EM Hatch/Seal Protective Covers							X														X		-	1		-	-
59	SM Hatch Cover & Seal							X	X															-	1		-	-
	SERVICING																											
60	Ground Servicing & Cooling Unit			X	X				X			X								X		X		1	1		1	1
61	GO_2 Transfer & Servicing Unit								X			X	X		X									-	1		-	1
62	GN_2 Transfer & Servicing Unit								X			X	X		X									-	1		-	1
63	Freon Transfer & Servicing Unit			X	X				X			X								X		X		1	1		1	1
64	Vacuum Servicing Unit				X				X			X			X					X		X		1	1		-	-
65	O_2/N_2 Pressure Unit								X			X	X		X									-	1		-	-

Table 5.2-2. Concepts II and IV Ground Support Equipment Requirements (Cont)

CONCEPT II & IV				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
LS/LS	LS/LS	IC/U	IC/U	LS/LS

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/PALLET SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC (II/U (IV)	ACTIVE LS (II & IV)	SPARES IC (II/U (IV)	SPARES LS (II & IV)
	NASA-SUPPLIED																										
	HANDLING																										
1	Weight & Balance Sling								X															-	1	-	-
2	Alignment Kit		X		X			X				X												1	1	1	1
3	Cargo Lift Trailer						X												X					1	1	-	-
4	Air Transport Tie Down Kit (C-5A)						X												X					1	-	-	-
5	Mobile Hoist/ Sling		X																	X		X		1	1	-	-
6	Small Equipment Transport Carts		X	X	X	X			X			X			X					X		X		5	5	-	-
7	Space Lab Shipping Canister (747)						X					X			X				X					1*	-	-	-
8	Spacelab Shipping Canister Sling						X					X			X				X					1*	-	-	-
	CHECKOUT																										
9	EMI Test Equipment				X				X			X												1	1	-	-
10	Electrical Load Banks											X												-	1	-	-
11	Optical Measurement Unit								X															-	1	-	-
	AUXILIARY																										
12	Battery Activity Unit											X												-	1	-	1
13	Clean Enclosure (10K Portable)								X			X												-	2	-	-
	Weight & Balance Kit																										
14	- Weight & Balance Measuring Equipment								X															-	1	-	1
15	Structural Repair Kit		X		X				X			X	X							X		X		1	1	-	-
16	Cleaning Kit		X		X		X	X	X			X	X							X		X		1	1	-	-
17	Transportation Instrumentation Kit						X												X					1*	-	-	-
18	Flow Rate Test Set			X	X				X											X				1	1	-	-

*Caravaned Item.

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Table 5.2-2. Concepts II and IV Ground Support Equipment Requirements (Cont)

CONCEPT II & IV				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
LS/LS	LS/LS	IC/U	IC/U	LS/LS

TEST/OPERATION: 1.0 EXPERIMENT SHIPMENT; 2.0 EXPERIMENT INSTALLATION; 3.0 CONNECT SM INTERFACE SIM.; 4.0 EXPERIMENT INTEGRATION; 5.0 GSE DISCONNECT; 6.0 RACKS/PALLET SHIPMENT; 7.0 MATE RACKS/PALLET -EM/SM SHELLS; 8.0 SPACELAB INTEGRATION; 9.0 SPACELAB SHIPMENT TO LS.; 10.0 SPACELAB OFFLOAD; 11.0 ORBITER CARGO INTEGRATION; 12.0 LAUNCH OPERATIONS; 13.0 MISSION OPERATIONS (REF); 14.0 POST-FLIGHT OPERATIONS; 15.0 SPACELAB MOVE TO MSOB; 16.0 SPACELAB SHIPMENT FROM LS; 17.0 DEMATE EM/SM SHELLS; 18.0 RACKS/PALLET SHIPMENT; 19.0 REFURBISH RACKS/PALLET; 20.0 EXPERIMENT SHIPMENT; 21.0 REFURB SUPPORT SYST & EM/SM SHELLS; 22.0 POST-REFURB RACKS/PALLET SHIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	QUANTITY REQUIREMENTS ACTIVE IC (II)/U (IV)	ACTIVE LS (II & IV)	SPARES IC (II)/U (IV)	SPARES LS (II & IV)
	NASA-SUPPLIED																										
	AUXILIARY (Cont.)																										
19	Leak Detector/MSS Spectrometer			X	X				X			X	X		X					X		X		1	1	1	1
20	X-Ray Unit		X						X			X								X		X		1	1	-	-
21	Installation Tool Kit (Gask-O-Seal)		X					X												X		X		1	1	-	-
22	SL Safing Equipment Set														X									-	1	-	-
23	General Purpose Lab Equip. Set			X	X			X	X			X	X							X		X		1	1	-	-
24	Ground Air Conditioning Unit (Personnel)								X			X	X		X							X		-	1	-	1
	SERVICING																										
25	Trace Gas Servicer			X	X				X			X	X		X					X		X		1	1	-	-
26	Cryogenic Servicing Unit												X											-	1	-	-
27	Hypergolic Servicing Unit												X		X									-	1	-	-

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Table 5.2-3. Concept III Ground Support Equipment Requirements

CONCEPT III				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
LS	LS	IC	U	LS

TEST/OPERATION: 1.0 EXPERIMENT SHIPMENT; 2.0 EXPERIMENT INSTALLATION; 3.0 CONNECT SM INTERFACE SIM.; 4.0 EXPERIMENT INTEGRATION; 5.0 GSE DISCONNECT; 6.0 RACKS/PALLET SHIPMENT; 7.0 MATE RACKS/PALLET -EM/SM SHELLS; 8.0 SPACELAB INTEGRATION; 9.0 SPACELAB SHIPMENT TO LS; 10.0 SPACELAB OFFLOAD; 11.0 ORBITER CARGO INTEGRATION; 12.0 LAUNCH OPERATIONS; 13.0 MISSION OPERATIONS (REF); 14.0 POST-FLIGHT OPERATIONS; 15.0 SPACELAB MOVE TO MSOB; 16.0 SPACELAB SHIPMENT FROM LS; 17.0 DEMATE EM/SM SHELLS; 18.0 RACKS/PALLET SHIPMENT; 19.0 REFURBISH RACKS/PALLET; 20.0 EXPERIMENT SHIPMENT; 21.0 REFURB SUPPORT SYST & EM/SM SHELLS; 22.0 POST-REFURB RACKS/PALLET SHIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	ACTIVE IC	ACTIVE U	ACTIVE LS	SPARES IC	SPARES U	SPARES LS
	ESRO-SUPPLIED																												
	HANDLING																												
	Interior Access Kit																												
1	- Contingency Entry Kit Vertical												X											-	-	1	-	-	-
2	- Horizontal Entry Kit											X												-	-	1	-	-	-
	Exterior Access Kit																												
3	- Scaffolding (ESRO Commercial type)						X	X	X			X				X		X					X	1	1	2	-	-	-
4	- Auxiliary Floor Panels-Pallets		X		X																			-	1	-	-	-	-
	Sling Assembly Kits																												
5	- End Cone Sling Set		X																	X			X	1	1	-	-	-	-
6	- Vertical Sling Kit												X											-	-	1	-	-	-
7	- Horizontal Sling Kit						X		X			X			X	X			X				X	1	1	1	-	-	-
8	- Igloo Handling Kit				NOT APPLICABLE																								
9	- Upper Handling Cage-Module								X			X			X	X								-	-	1	-	-	-
10	- Lower Handling Cage-Module								X			X			X	X								-	-	1	-	-	-
11	- Upper Handling Cage-Pallet						X		X			X			X	X			X				X	1	1	1	-	-	-
12	- Handling Platform-Pallet						X		X			X			X	X			X				X	1	1	1	-	-	-
13	- Utility Bridge Handling Kit		X																X				X	1	1	-	-	-	-
	Storage Fixtures																												
14	- EM Storage Fixture																					X		-	-	1	-	-	-
15	- SM Storage Fixture																					X		-	-	1	-	-	-
16	- Pallet Storage Fixture																			X				1	-	-	-	-	-
17	- Rack/Rack Set/Floor Assy.																			X				1	-	-	-	-	-
18	Main Assembly Stand		X		X			X	X							X		X		X				1	1	2	-	-	-
19	Alignment Work Stand							X										X						-	-	1	-	-	-

Table 5.2-3. Concept III Ground Support Equipment Requirements (Cont)

CONCEPT III				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
LS	LS	IC	U	LS

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/PALLET SHIPMENT	QUANTITY REQUIREMENTS: ACTIVE IC	ACTIVE U	ACTIVE LS	SPARES IC	SPARES U	SPARES LS
	ESRO-SUPPLIED																												
	HANDLING (Cont.)																												
20	Aft End Cone Stand		X																	X			X	1	1	-	-	-	-
21	End Cone Support		X		X		X	X										X	X	X			X	1	1	-	-	-	-
22	Rack & Floor Rail Set							X										X						-	-	1	-	-	-
	Transporters																												
23	- Transporter Platform-Module											X			X	X		X				X		-	-	1	-	-	-
24	- Transporter Platform-End Cone		X				X											X	X	X			X	1*	-	-	-	-	-
25	- Transporter Platform-Rack/ Rack Set/Floor						X					X			X	X		X	X	X			X	1*	-	-	-	-	-
26	- Transport Trailer						X					X			X	X		X	X	X			X	1	1	1	-	-	-
	CHECKOUT																												
27	Data Processing Equipment			X	X				X															-	1	1	-	1	1
28	Ground Power Supply			X	X				X															-	1	1	-	1	1
29	Electrical Power Test Set			X	X				X															-	1	1	-	-	-
	Simulators																												
30	- Support Module Simulator			X	X																			-	1	-	-	1	-
31	- Orbiter I/F Simulator								X															-	-	1	-	-	1
32	Control & Data Acquisition Console			X	X				X															-	1	1	-	1	1
	Cable Kits																												
33	- Ground Test Remote Site Cable Kit				X				X			X												-	1	1	-	-	-
34	- Launch Support (Vertical) Cable Kit																							-	-	1			

*Caravaned item.

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Table 5.2-3. Concept III Ground Support Equipment Requirements (Cont)

CONCEPT III				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
LS	LS	IC	U	LS

TEST/OPERATION: 1.0 EXPERIMENT SHIPMENT; 2.0 EXPERIMENT INSTALLATION; 3.0 CONNECT SM INTERFACE SIM.; 4.0 EXPERIMENT INTEGRATION; 5.0 GSE DISCONNECT; 6.0 RACKS/PALLET SHIPMENT; 7.0 MATE RACKS/PALLET -EM/SM SHELLS; 8.0 SPACELAB INTEGRATION; 9.0 SPACELAB SHIPMENT TO LS; 10.0 SPACELAB OFFLOAD; 11.0 ORBITER CARGO INTEGRATION; 12.0 LAUNCH OPERATIONS; 13.0 MISSION OPERATIONS (REF); 14.0 POST-FLIGHT OPERATIONS; 15.0 SPACELAB MOVE TO MSOB; 16.0 SPACELAB SHIPMENT FROM LS; 17.0 DEMATE EM/SM SHELLS; 18.0 RACKS/PALLET SHIPMENT; 19.0 REFURBISH RACKS/PALLET; 20.0 EXPERIMENT SHIPMENT; 21.0 REFURB SUPPORT SYST & EM/SM SHELLS; 22.0 POST-REFURB RACKS/PALLET SHIPMENT

QUANTITY REQUIREMENTS: ACTIVE (IC, U, LS); SPARES (IC, U, LS)

LINE ITEM	GSE NOMENCLATURE	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	Active IC	Active U	Active LS	Spares IC	Spares U	Spares LS
	ESRO-SUPPLIED																												
	CHECKOUT (Cont.)																												
	Cable Kits (Cont.)																												
35	- Subsystem Test Cable Kit								X															-	-	1	-	-	-
36	- Experiment Test Cable Kit				X																			-	1	-	-	-	-
37	- Prelaunch Servicing Cable Kit											X	X											-	-	2	-	-	-
38	- Recovery Cable Kit														X									-	-	1	-	-	-
39	- Electrical System Test Cable Kit								X			X												-	-	1	-	-	-
40	- GSE/Facility Cable Kit				X				X			X												-	1	1	-	-	-
41	- Memory Load & Verify Unit			X	X				X															-	1	1	-	1	1
42	- ECLSS Test Unit								X			X	X											-	-	1	-	-	-
43	- Continuity Test & Equipment		X	X	X			X	X			X												-	1	1	-	-	-
44	- SL Module Universal Seal Test Console								X			X	X											-	-	1	-	-	1
	AUXILIARY																												
45	Lighting Kit		X		X			X	X			X	X				X					X		-	1	2	-	-	-
46	Ground Air Cooling Unit (Equipment)			X	X				X															-	1	1	-	1	1
	Environmental Control Kit - Transport/Storage																												
47	- Environmental Soft Cover-Mod.											X			X									-	-	1	-	-	-
48	- Environmental Soft Cover - Rack/Pallet						X					X			X				X				X	1*	-	-	-	-	-
49	- Environmental Soft Cover - Utility Bridge						X					X			X				X				X	1	-	-	-	-	-
50	- Environmental Soft Cover-Pallet						X					X			X				X				X	1	-	-	-	-	-
51	- Environmental Soft Cover - End Cone						X					X			X				X				X	1	-	-	-	-	-

*Caravaned Items.

Table 5.2-3. Concept III Ground Support Equipment Requirements (Cont)

CONCEPT III				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
LS	LS	IC	U	LS

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/ PALLET SHIPMENT	ACTIVE IC	ACTIVE U	ACTIVE LS	SPARES IC	SPARES U	SPARES LS
	ESRO-SUPPLIED																												
	AUXILIARY (Cont.)																												
	Protector Cover Kits																												
52	- Module Transporter-Protective Cover																							-	-	1			
53	- End Cone Transporter - Protective Cover		When transporters are not in use, these protective covers will be used.																					1	-	-			
54	- Racks/Rack Set/Floor Assy, Transporter - PC																							1*	-	-			
55	- Transporter Trailer - Protective Cover																							1	1	1			
56	Transducer/Gage Calibration Kit		X		X				X			X	X							X		X		1	1	1	-	1	-
57	Interior Protective Devices							X	X			X	X			X		X						-	1	-	-	-	-
58	SM/EM Hatch/Seal Protective Covers							X														X		-	-	1	-	-	-
59	SM Hatch Cover and Seal							X	X															-	-	1	-	-	-
	SERVICING																												
60	Ground Servicing & Cooling Unit			X	X				X			X								X		X		1	1	1	-	1	1
61	GO_2 Transfer & Servicing Unit								X			X	X		X									-	-	1	-	-	1
62	GN_2 Transfer & Servicing Unit								X			X	X		X									-	-	1	-	-	1
63	Freon Transfer & Servicing Unit			X	X				X			X								X		X		1	1	1	1	1	1
64	Vacuum Servicing Unit				X				X			X			X					X		X		1	1	1	-	-	-
65	O_2/N_2 Pressure Unit								X			X	X		X									-	-	1	-	-	-

*Caravaned item.

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Table 5.2-3. Concept III Ground Support Equipment Requirements (Cont)

CONCEPT III				
OWNER				INTEG. SITE
SM	EM	P	EXPMT EQUIP	SL
LS	LS	IC	U	LS

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS.	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/PALLET SHIPMENT	ACTIVE IC	ACTIVE U	ACTIVE LS	SPARES IC	SPARES U	SPARES LS
	NASA-SUPPLIED																												
	HANDLING																												
1	Weight and Balance Sling								X															-	-	1	-	-	-
2	Alignment Kit		X		X			X				X											X	1	1	1	1	1	1
3	Cargo Lift Trailer						X												X				X	1	1	1	-	-	-
4	Air Transport Tie Down Kit (C-5A)						X												X				X	1*	-	-	-	-	-
5	Mobile Hoist/Sling		X																	X		X		1	1	1	-	-	-
6	Small Equipment Transport Carts		X	X	X	X			X			X			X					X		X		5	5	5	-	-	-
7	Space Lab Shipping Canister (747)						X					X			X				X				X	1*	-		-	-	-
8	Spacelab Shipping Canister Sling						X					X			X				X				X	1*	-	-	-	-	-
	CHECKOUT																												
9	EMI Test Equipment				X				X			X												-	1	1	-	-	-
10	Electrical Load Banks											X												-	-	1	-	-	-
11	Optical Measurement Unit								X															-	-	1	-	-	-
	AUXILIARY																												
12	Battery Activity Unit											X												-	-	1	-	-	1
13	Clean Enclosure (10K Portable)								X			X												-	-	2	-	-	-
	Weight and Balance Kit																												
14	- Weight and balance Measuring Equipment								X															-	-	1	-	-	1
15	Structural Repair Kit		X	X					X			X	X							X		X		1	1	1	-	-	-
16	Cleaning Kit		X	X			X	X	X			X	X							X		X		1	1	1	-	-	-
17	Transportation Instrumentation Kit						X												X				X	1*	-	-	-	-	-

*Caravaned items.

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Table 5.2-3. Concept III Ground Support Equipment Requirements (Cont)

CONCEPT III				
OWNER			INTEG. SITE	
SM	EM	P	EXPMT EQUIP	SL
LS	LS	IC	U	LS

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION	3.0 CONNECT SM INTERFACE SIM.	4.0 EXPERIMENT INTEGRATION	5.0 GSE DISCONNECT	6.0 RACKS/PALLET SHIPMENT	7.0 MATE RACKS/PALLET -EM/SM SHELLS	8.0 SPACELAB INTEGRATION	9.0 SPACELAB SHIPMENT TO LS.	10.0 SPACELAB OFFLOAD	11.0 ORBITER CARGO INTEGRATION	12.0 LAUNCH OPERATIONS	13.0 MISSION OPERATIONS (REF)	14.0 POST-FLIGHT OPERATIONS	15.0 SPACELAB MOVE TO MSOB	16.0 SPACELAB SHIPMENT FROM LS	17.0 DEMATE EM/SM SHELLS	18.0 RACKS/PALLET SHIPMENT	19.0 REFURBISH RACKS/PALLET	20.0 EXPERIMENT SHIPMENT	21.0 REFURB SUPPORT SYST & EM/SM SHELLS	22.0 POST-REFURB RACKS/ PALLET SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC	ACTIVE U	ACTIVE LS	SPARES IC	SPARES U	SPARES LS
	NASA-SUPPLIED																												
	AUXILIARY (Cont.)																												
18	Flow Rate Test Set			X	X				X											X		X		1	1	1	-	-	-
19	Leak Detector/MMS Spectrometer			X	X				X			X	X		X					X		X		1	1	1	1	1	1
20	X-Ray Unit		X						X			X								X		X		1	1	1	-	-	-
21	Installation Tool Kit (Gask-O-Seal)		X	X			X													X		X		1	1	1	-	-	-
22	SL Safing Equipment Set														X									-	-	1	-	-	-
23	General Purpose Lab Equip Set			X	X			X	X			X	X							X		X		1	1	1	-	-	-
24	Ground Air Conditioning Unit (Personnel)								X			X	X		X							X		-	-	1	-	-	1
	SERVICING																												
25	Trace Gas Servicer			X	X				X			X	X		X					X		X		1	1	1	-	-	-
26	Cryogenic Servicing Unit												X											-	-	1	-	-	-
27	Hypergolic Servicing Units												X		X									-	-	1	-	-	-

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Table 5.2-4. Concept VI Ground Support Equipment Requirements

CONCEPT VI			
OWNER		INTEG. SITE	
IGLOO*	P	EXPMT EQUIP	SL
LS	IC	U	LS

*SUPPORT SYSTEM IGLOO AND EQUIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION (P/IGL)	3.0 CONNECT & C/O IGL/ORB SIMULATOR SET	4.0 EXPERIMENT C/O & INTEGRATION	5.0 GSE DISCONNECT	6.0 PALLET/IGLOO SHIPMENT	7.0 P/IGL & PSS EQUIP ARRIVAL & R/I	8.0 MATE PALLET/IGLOO (SUPPORT SYSTEMS)	9.0 SPACELAB INTEGRATION	10.0 ORBITER CARGO INTEGRATION	11.0 LAUNCH OPERATIONS	12.0 MISSION OPERATIONS (REF)	13.0 POST FLIGHT OPERATIONS	14.0 REFURBISH SUPPORT SYSTEMS IGLOO	15.0 PALLET/IGLOO SHIPMENT	16.0 REMOVE EXPMTS/EQUIP FROM P/IGL	17.0 EXPERIMENT SHIPMENT	18.0 REFURB/RECONFIGURE PALLET & IGLOOS	19.0 POST REFURB PALLET/IGLOO SHIPMENT	ACTIVE IC	ACTIVE U	ACTIVE LS	SPARES IC	SPARES U	SPARES LS
	ESRO-SUPPLIED																									
	HANDLING																									
	Interior Access Kit																									
1	- Contingency Entry Kit Vertical							NOT APPLICABLE																		
2	- Horizontal Entry Kit							NOT APPLICABLE																		
	EXTERIOR ACCESS KIT																									
3	- Scaffolding (ESRO Comm. type)						X		X	X	X			X		X				X	1	1	2	-	-	-
4	- Auxiliary Floor Panels - Pallets		X		X																-	1	-	-	-	-
	SLING ASSEMBLY KITS																									
5	- End Cone Sling Set							NOT APPLICABLE																		
6	- Vertical Sling Kit											X									-	-	1	-	-	-
7	- Horizontal Sling Kit						X			X	X			X		X				X	1	1	1	-	-	-
8	- Igloo Handling Kit								X					X	X						-	-	1	-	-	-
9	- Upper Handling Cage-Module							NOT APPLICABLE																		
10	- Lower Handling Cage-Module							NOT APPLICABLE																		
11	- Upper Handling Cage-Pallet						X			X	X			X		X				X	1	1	1	-	-	-
12	- Handling Platform - Pallet						X			X	X			X		X				X	1	1	1	-	-	-
13	- Utility Bridge Handling Kit							NOT APPLICABLE																		
	STORAGE FIXTURES																									
14	- EM Storage Fixture							NOT APPLICABLE																		
15	- SM Storage Fixture							NOT APPLICABLE																		
16	- Pallet Storage Fixture																		X		1	-	-	-	-	-
17	- Rack/Rack Set/Floor Assy.																		X		1	-	-	-	-	-
18	Main Assembly Stand		X		X				X	X									X		1	1	2	-	-	-
19	Alignment Work Stand								X												-	-	1	-	-	-

Table 5.2-4. Concept VI Ground Support Equipment Requirements (Cont)

CONCEPT VI			
OWNER		INTEG. SITE	
IGLOO*	P	EXPMT EQUIP	SL
LS	IC	U	LS

*SUPPORT SYSTEM IGLOO AND EQUIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION (P/IGL)	3.0 CONNECT & C/O IGL/ORB SIMULATOR SET	4.0 EXPERIMENT C/O & INTEGRATION	5.0 GSE DISCONNECT	6.0 PALLET/IGLOO SHIPMENT	7.0 P/IGL & PSS EQUIP ARRIVAL & R/I	8.0 MATE PALLET/IGLOO (SUPPORT SYSTEM)	9.0 SPACELAB INTEGRATION	10.0 ORBITER CARGO INTEGRATION	11.0 LAUNCH OPERATIONS	12.0 MISSION OPERATIONS (REF)	13.0 POST FLIGHT OPERATIONS	14.0 REFURBISH SUPPORT SYSTEMS IGLOO	15.0 PALLET/IGLOO SHIPMENT	16.0 REMOVE EXPMTS/EQUIP FROM P/IGL	17.0 EXPERIMENT SHIPMENT	18.0 REFURB/RECONFIGURE PALLET & IGLOOS	19.0 POST REFURB PALLET/GLOO SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC	ACTIVE U	ACTIVE LS	SPARES IC	SPARES U	SPARES LS
	ESRO-SUPPLIED																									
	HANDLING																									
20	Aft End Cone Stand							NOT APPLICABLE																		
21	End Cone Support							NOT APPLICABLE																		
22	Rack & Floor Rail Set							NOT APPLICABLE																		
	Transporters																									
23	- Transporter Platform-Module							NOT APPLICABLE																		
24	- Transporter Platform-End Cone							NOT APPLICABLE																		
25	- Transporter Platform-Rack/Rack Set/Floor						X				X			X		X				X	1*	-	-	-	-	-
26	- Transport Trailer						X				X			X		X				X	1	1	1	-	-	-
	CHECKOUT																									
27	Data Processing Equipment			X	X					X											-	1	1	-	1	1
28	Ground Power Supply			X	X					X											-	1	1	-	1	1
29	Electrical Power Test Set			X	X					X											-	1	1	-	-	-
	Simulators																									
30	- SSIGLOO Simulator Set			X	X																-	1	-	-	1	-
31	- Orbiter I/F Simulator			X	X					X											-	1	1	-	1	1
32	Control & Data Acquisition Console			X	X					X											-	1	1	-	1	1
	Cable Kits																									
33	- Ground Test Remote Site Cable Kit				X					X	X										-	1	1	-	-	-
34	- Launch Support (Vertical) Cable Kit											X									-	-	1	-	-	-
35	- Subsystem Test Cable Kit									X											-	-	1	-	-	-
36	- Experiment Test Cable Kit				X																-	1	-	-	-	-
37	- Prelaunch Servicing Cable Kit										X	X									-	-	2	-	-	-
38	- Recovery Cable Kit													X							-	-	1	-	-	-

*Caravaned Items

Table 5.2-4. Concept VI Ground Support Equipment Requirements (Cont)

CONCEPT VI			
OWNER		INTEG. SITE	
IGLOO*	P	EXPMT EQUIP	SL
LS	IC	U	LS

*SUPPORT SYSTEM IGLOO AND EQUIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION (P/IGL)	3.0 CONNECT & C/O IGL/ORB SIMULATOR SET	4.0 EXPERIMENT C/O & INTEGRATION	5.0 GSE DISCONNECT	6.0 PALLET/IGLOO SHIPMENT	7.0 P/IGL & PSS EQUIP ARRIVAL & R/I	8.0 MATE PALLET/IGLOO (SUPPORT SYSTEMS)	9.0 SPACELAB INTEGRATION	10.0 ORBITER CARGO INTEGRATION	11.0 LAUNCH OPERATIONS	12.0 MISSION OPERATIONS (REF)	13.0 POST FLIGHT OPERATIONS	14.0 REFURBISH SUPPORT SYSTEMS IGLOO	15.0 PALLET/IGLOO SHIPMENT	16.0 REMOVE EXPMTS/EQUIP FROM P/IGL	17.0 EXPERIMENT SHIPMENT	18.0 REFURB/RECONFIGURE PALLET & IGLOOS	19.0 POST REFURB PALLET/IGLOO SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC	ACTIVE U	ACTIVE LS	SPARES IC	SPARES U	SPARES LS
	ESRO-SUPPLIED																									
	CHECKOUT (Cont'd.)																									
39	- Electrical System Test Cable Kit									X	X										-	-	1	-	-	-
40	- GSE/Facility Cable Kit				X					X	X										-	1	1	-	-	-
41	Memory Load & Verify Unit			X	X					X											-	1	1	-	1	1
42	ECLSS Test Unit									X	X	X									-	-	1	-	-	-
43	Continuity Test Equipment		X	X	X				X	X	X										-	1	1	-	-	-
44	SL Module Universal Seal Test Console									X	X	X									-	-	1	-	-	1
	AUXILIARY																									
45	Lighting Kit		X		X					X				X							-	1	2	-	-	-
46	Ground Air Cooling Unit (Equipment)			X	X					X											-	1	1	-	1	1
	Environmental Control Kit-Transport/ Storage																									
47	- Environmental Soft Cover-Module							NOT APPLICABLE																		
48	- Environmental Soft Cover - Rack/ Pallet							NOT APPLICABLE																		
49	- Environmental Soft Cover - Utility Bridge							NOT APPLICABLE																		
50	- Environmental Soft Cover-Pallet						X				X			X		X				X	1*	-	-	-	-	-
51	- Environmental Soft Cover-End Cone							NOT APPLICABLE																		
	Protector Cover Kits																									
52	- Module Transporter-Protective Cover							NOT APPLICABLE																		
53	- End Cone Transporter-Protective Cover	WHEN TRANSPORTERS						NOT APPLICABLE																		
54	- Racks/Rack Set/Floor Assy. Transporter-PC	ARE NOT IN USE THESE PROTECTIVE COVERS WILL																								
55	- Transporter Trailer-Protective Cover	BE USED																			1	1	1			
56	Transducer/Cage Calibration Kit		X		X					X	X	X				X			X		1	1	1	-	1	-

*Caravaned Items

Table 5.2-4. Concept VI Ground Support Equipment Requirements (Cont)

CONCEPT VI			
OWNER		INTEG. SITE	
IGLOO*	P	EXPMT EQUIP	SL
LS	IC	U	LS

*SUPPORT SYSTEM IGLOO AND EQUIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION (P/IGL)	3.0 CONNECT & C/O IGL/ ORB SIMULATOR SET	4.0 EXPERIMENT C/O & INTEGRATION	5.0 GSE DISCONNECT	6.0 PALLET/IGLOO SHIPMENT	7.0 P/IGL & PSS EQUIP ARRIVAL & R/I	8.0 MATE PALLET/IGLOO (SUPPORT SYSTEMS)	9.0 SPACELAB INTEGRATION	10.0 ORBITER CARGO INTEGRATION	11.0 LAUNCH OPERATIONS	12.0 MISSION OPERATIONS (REF)	13.0 POST FLIGHT OPERATIONS	14.0 REFURBISH SUPPORT SYSTEMS IGLOO	15.0 PALLET/IGLOO SHIPMENT	16.0 REMOVE EXPMTS/ EQUIP FROM P/IGL	17.0 EXPERIMENT SHIPMENT	18.0 REFURB/RECONFIGURE PALLET & IGLOOS	19.0 POST REFURB PALLET/ IGLOO SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC	ACTIVE U	ACTIVE LS	SPARES IC	SPARES U	SPARES LS
	ESRO-SUPPLIED																									
	AUXILIARY (Cont'd.)																									
57	Interior Protective Devices							NOT APPLICABLE																		
58	SM/EM Hatch/Seal Protective Covers							NOT APPLICABLE																		
59	SM Hatch Cover & Seal							NOT APPLICABLE																		
	SERVICING																									
60	Ground Servicing & Cooling Unit			X	X					X	X				X				X		1	1	1	1	1	1
61	GO_2 Transfer & Servicing Unit									X	X	X		X							-	-	1	-	-	1
62	GN_2 Transfer & Servicing Unit									X	X	X		X							-	-	1	-	-	1
63	Freon Transfer & Servicing Unit			X	X					X											1	1	1	-	-	-
64	Vacuum Servicing Unit				X					X	X			X	X				X		1	1	1	-	-	-
65	O_2/N_2 Pressure Unit									X	X	X		X							-	-	1	-	-	-

Table 5.2-4. *Concept VI Ground Support Equipment Requirements (Cont)*

CONCEPT VI			
OWNER		INTEG. SITE	
IGLOO*	P	EXPMT EQUIP	SL
LS	IC	U	LS

*SUPPORT SYSTEM IGLOO AND EQUIPMENT

TEST/OPERATION: 1.0 EXPERIMENT SHIPMENT; 2.0 EXPERIMENT INSTALLATION (P/IGL); 3.0 CONNECT & C/O IGL/ORB SIMULATOR SET; 4.0 EXPERIMENT C/O & INTEGRATION; 5.0 GSE DISCONNECT; 6.0 PALLET/IGLOO SHIPMENT; 7.0 P/IGL & PSS EQUIP ARRIVAL & R/I; 8.0 MATE PALLET/IGLOO (SUPPORT SYSTEMS); 9.0 SPACELAB INTEGRATION; 10.0 ORBITER CARGO INTEGRATION; 11.0 LAUNCH OPERATIONS; 12.0 MISSION OPERATIONS (REF); 13.0 POST FLIGHT OPERATIONS; 14.0 REFURBISH SUPPORT SYSTEMS IGLOO; 15.0 PALLET/IGLOO SHIPMENT; 16.0 REMOVE EXPMTS/EQUIP FROM P/IGL; 17.0 EXPERIMENT SHIPMENT; 18.0 REFURB/RECONFIGURE PALLET & IGLOOS; 19.0 POST REFURB PALLET/IGLOO SHIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	ACTIVE IC	ACTIVE U	ACTIVE LS	SPARES IC	SPARES U	SPARES LS
	NASA-SUPPLIED																									
	HANDLING																									
1	Weight & Balance Sling									X											-	-	1	-	-	-
2	Alignment Kit		X		X				X		X										-	1	1	-	1	1
3	Cargo Lift Trailer						X									X				X	1	1	1	-	-	-
4	Air Transport Tie Down Kit (C-5A)						X									X				X	1*	-	-	-	-	-
5	Mobile Hoist/Sling		X											X	X				X		1	1	1	-	-	-
6	Small Equipment Export Carts		X	X	X	X				X	X			X	X				X		5	5	5	-	-	-
7	Spacelab Shipping Canister (747)						X									X				X	1*	-	-	-	-	-
8	Spacelab Shipping Canister Sling						X									X				X	1*	-	-	-	-	-
	CHECKOUT																									
9	EMI Test Equipment				X					X	X										-	1	1	-	-	-
10	Electrical Load Banks										X										-	-	1	-	-	-
11	Optical Measurement Unit									X											-	-	1	-	-	-
	AUXILIARY																									
12	Battery Activity Unit										X										-	-	1	-	-	1
13	Clean Enclosure (10K Portable)									X	X										-	-	2	-	-	-
	Weight & Balance Kit																									
14	- Weight & Balance Measuring Equipment									X											-	-	1	-	-	1

*Caravaned Items

Space Division
Rockwell International

Table 5.2-4. Concept VI Ground Support Equipment Requirements (Cont)

CONCEPT VI			
OWNER		INTEG. SITE	
IGLOO*	P	EXPMT EQUIP	SL
LS	IC	U	LS

*SUPPORT SYSTEM IGLOO AND EQUIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION (P/IGL)	3.0 CONNECT & C/O IGL/ORB SIMULATOR SET	4.0 EXPERIMENT C/O & INTEGRATION	5.0 GSE DISCONNECT	6.0 PALLET/IGLOO SHIPMENT	7.0 P/IGL & PSS EQUIP ARRIVAL & R/I	8.0 MATE PALLET/IGLOO (SUPPORT SYSTEMS)	9.0 SPACELAB INTEGRATION	10.0 ORBITER CARGO INTEGRATION	11.0 LAUNCH OPERATIONS	12.0 MISSION OPERATIONS (REF)	13.0 POST FLIGHT OPERATIONS	14.0 REFURBISH SUPPORT SYSTEMS IGLOO	15.0 PALLET/IGLOO SHIPMENT	16.0 REMOVE EXPMTS/EQUIP FROM P/IGL	17.0 EXPERIMENT SHIPMENT	18.0 REFURB/RECONFIGURE PALLET & IGLOOS	19.0 POST REFURB PALLET/IGLOO SHIPMENT	ACTIVE IC	ACTIVE U	ACTIVE LS	SPARES IC	SPARES U	SPARES LS
	NASA-SUPPLIED																									
	AUXILIARY (Cont'd.)																									
15	Structural Repair Kit		X	X						X	X				X				X		1	1	1	-	-	-
16	Cleaning Kit		X	X			X		X	X	X				X				X		1	1	1	-	-	-
17	Transportation Instrumentation Kit						X									X				X	1*	-	-	-	-	-
18	Flow Rate Test Set			X	X					X					X				X		1	1	1	-	-	-
19	Leak Detector/MMS Spectrometer			X	X					X	X	X		X	X				X		1	1	1	1	1	1
20	X-Ray Unit		X							X	X				X				X		1	1	1	-	-	-
21	Installation Tool Kit (GASK-O Seal)		X						X						X				X		1	1	1	-	-	-
22	SL Safing Equipment Set													X							-	-	1	-	-	-
23	General Purpose Lab Equip Set			X	X					X	X	X			X				X		1	1	1	-	-	-
24	Ground Air Conditioning Unit (Personnel)	NOT APPLICABLE																								
	SERVICING																									
25	Trace Gas Servicer			X	X					X	X	X		X	X				X		1	1	1	-	-	-
26	Cryogenic Servicing Unit											X									-	-	1	-	-	-
27	Hypergolic Servicing Units											X		X							-	-	1	-	-	-

*Caravaned Item

Table 5.2-5. Concepts VII and VIII Ground Support Equipment Requirements

CONCEPT VII & VIII			
OWNER		INTEG. SITE	
IGLOO*	P	EXPMT EQUIP	SL
LS / LS	IC / U	IC / U	LS / LS

*SUPPORT SYSTEMS IGLOO & EQUIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION (P/IGL)	3.0 CONNECT & C/O IGL/ ORB SIMULATOR SET	4.0 EXPERIMENT C/O & INTEGRATION	5.0 GSE DISCONNECT	6.0 PALLET/IGLOO SHIPMENT	7.0 P/IGL & PSS EQUIP ARRIVAL & R/I	8.0 MATE PALLET/IGLOO (SUPPORT SYSTEMS)	9.0 SPACELAB INTEGRATION	10.0 ORBITER CARGO INTEGRATION	11.0 LAUNCH OPERATIONS	12.0 MISSION OPERATIONS (REF)	13.0 POST FLIGHT OPERATIONS	14.0 REFURBISH SUPPORT SYSTEMS IGLOO	15.0 PALLET/IGLOO SHIPMENT	16.0 REMOVE EXPMTS/ EQUIP FROM P/IGL	17.0 EXPERIMENT SHIPMENT	18.0 REFURB/RECONFIGURE PALLET & IGLOOS	19.0 POST REFURB PALLET/ IGLOO SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC(VII)/U(VIII)	ACTIVE LS(VII & VIII)	SPARES IC(VII)/U(VIII)	SPARES LS(VII & VIII)
	ESRO-SUPPLIED																							
	HANDLING																							
	Interior Access Kit																							
1	- Contingency Entry Kit Vertical							NOT APPLICABLE																
2	- Horizontal Entry Kit							NOT APPLICABLE																
	Exterior Access Kit																							
3	- Scaffolding (ESRO Commercial Type)						X		X	X	X			X		X					2	1	-	-
4	- Auxiliary Floor Panels-Pallets		X		X																1	-	-	-
	Sling Assembly Kits																							
5	- End Cone Sling Set							NOT APPLICABLE																
6	- Vertical Sling Kit											X									-	1	-	-
7	- Horizontal Sling Kit						X			X	X			X		X					1	1	-	-
8	- Igloo Handling Kit								X					X	X						-	1	-	-
9	- Upper Handling Cage-Module							NOT APPLICABLE																
10	- Lower Handling Cage-Module							NOT APPLICABLE																
11	- Upper Handling Cage-Pallet						X			X	X			X		X					1	1	-	-
12	- Handling Platform-Pallet						X			X	X			X		X					1	1	-	-
13	- Utility Bridge Handling Kit							NOT APPLICABLE																
	Storage Fixtures																							
14	- EM Storage Fixture							NOT APPLICABLE																
15	- SM Storage Fixture							NOT APPLICABLE																
16	- Pallet Storage Fixture																		X		1	-	-	-
17	- Rack/Rack Set/Floor Assy																		X		1	-	-	-
18	Main Assembly Stand		X		X				X	X									X		2	1	-	-
19	Alignment Work Stand								X												-	1	-	-

Table 5.2-5. Concepts VII and VIII Ground Support Equipment Requirements (Cont)

CONCEPT VII & VIII			
OWNER		INTEG. SITE	
IGLOO*	P	EXPMT EQUIP	SL
LS / LS	IC / U	IC / U	LS / LS

*SUPPORT SYSTEMS IGLOO & EQUIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION(P/IGL)	3.0 CONNECT & C/O IGL/ORB SIMULATOR SET	4.0 EXPERIMENT C/O & INTEGRATION	5.0 GSE DISCONNECT	6.0 PALLET/IGLOO SHIPMENT	7.0 P/IGL & PSS EQUIP ARRIVAL & R/I	8.0 MATE PALLET/IGLOO (SUPPORT SYSTEMS)	9.0 SPACELAB INTEGRATION	10.0 ORBITER CARGO INTEGRATION	11.0 LAUNCH OPERATIONS	12.0 MISSION OPERATIONS (REF)	13.0 POST FLIGHT OPERATIONS	14.0 REFURBISH SUPPORT SYSTEMS IGLOO	15.0 PALLET/IGLOO SHIPMENT	16.0 REMOVE EXPMTS/EQUIP FROM P/IGL	17.0 EXPERIMENT SHIPMENT	18.0 REFURB/RECONFIGURE PALLET & IGLOOS	19.0 POST REFURB PALLET/IGLOO SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC(VII)/U(VIII)	ACTIVE LS(VII & VIII)	SPARES IC(VII)/U(VIII)	SPARES LS(VII & VIII)
	ESRO-SUPPLIED																							
	<u>HANDLING</u> (Cont'd.)																							
20	Aft End Cone Stand							NOT APPLICABLE																
21	End Cone Support							NOT APPLICABLE																
22	Rack & Floor Rail Set							NOT APPLICABLE																
	<u>Transporters</u>																							
23	- Transporter Platform-Module							NOT APPLICABLE																
24	- Transporter Platform-End Love							NOT APPLICABLE																
25	- Transporter Platform-Rack/ Rack Set/Floor						X				X			X		X					1*	-	-	-
26	- Transport Trailer						X				X			X		X					1	1	-	-
	<u>CHECKOUT</u>																							
27	Data Processing Equipment			X	X					X											1	1	1	1
28	Ground Power Supply			X	X					X											1	1	1	1
29	Electrical Power Test Set			X	X					X											1	1	-	-
	<u>Simulators</u>																							
30	- SSIGLOO Simulator Set			X	X																1	-	1	-
31	- Orbiter I/F Simulator			X	X					X											1	1	1	1
32	Control & Data Acquisition Console			X	X					X											1	1	1	1
	<u>Cable Kits</u>																							
33	- Ground Test Remote Site Cable Kit				X					X	X										1	1	-	-
34	- Launch Support (Vertical) Cable Kit											X									-	1	-	-
35	- Subsystem Test Cable Kit									X											-	1	-	-
36	- Experiment Test Cable Kit				X																1	-	-	-
37	- Prelaunch Servicing Cable Kit										X	X									-	2	-	-

*Caravaned Items

Table 5.2-5. Concepts VII and VIII Ground Support Equipment Requirements (Cont)

CONCEPT VII & VIII			
OWNER		INTEG. SITE	
IGLOO*	P	EXPMT EQUIP	SL
LS / LS	IC / U	IC / U	LS / LS

*SUPPORT SYSTEMS IGLOO & EQUIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION (P/IGL)	3.0 CONNECT & C/O IGL/ORB SIMULATOR SET	4.0 EXPERIMENT C/O & INTEGRATION	5.0 GSE DISCONNECT	6.0 PALLET/IGLOO SHIPMENT	7.0 P/IGL & PSS EQUIP ARRIVAL & R/I	8.0 MATE PALLET/IGLOO (SUPPORT SYSTEMS)	9.0 SPACELAB INTEGRATION	10.0 ORBITER CARGO INTEGRATION	11.0 LAUNCH OPERATIONS	12.0 MISSION OPERATIONS (REF)	13.0 POST FLIGHT OPERATIONS	14.0 REFURBISH SUPPORT SYSTEMS IGLOO	15.0 PALLET/IGLOO SHIPMENT	16.0 REMOVE EXPMTS/EQUIP FROM P/IGL	17.0 EXPERIMENT SHIPMENT	18.0 REFURB/RECONFIGURE PALLET & IGLOOS	19.0 POST REFURB PALLET/IGLOO SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC(VII)/U(VIII)	ACTIVE LS(VII & VIII)	SPARES IC(VII)/U(VIII)	SPARES LS(VII & VIII)
	ESRO-SUPPLIED																							
	CHECKOUT (Cont'd.)																							
38	- Recovery Cable Kit													X							-	1	-	-
39	- Electrical System Test Cable Kit									X	X										-	1	-	-
40	- GSE/Facility Cable Kit									X	X										-	1	-	-
41	Memory Load & Verify Unit			X	X					X											1	1	1	1
42	ECLSS Test Unit									X	X	X									-	1	-	-
43	Continuity Test Equipment		X	X	X				X	X	X										1	1	-	-
44	SL Module Universal Seal Test Console									X	X	X									-	1	-	1
	AUXILIARY																							
45	Lighting Kit		X		X					X				X							1	2	-	-
46	Ground Air Cooling Unit (Equip.)																				1	1	1	1
	Environ. Control Kit-Transp./Storage																							
47	- Environ. Soft Cover- Module									NOT APPLICABLE														
48	- Environ. Soft Cover- Rack/Pallet									NOT APPLICABLE														
49	- Environ. Soft Cover- Util. Bridge									NOT APPLICABLE														
50	- Environ. Soft Cover- Pallet					X					X			X		X					1*	-	-	-
51	- Environ. Soft Cover- End Cone									NOT APPLICABLE														
	Protector Cover Kits																							
52	- Module Transp.-Protective Cover									NOT APPLICABLE														
53	- End Cone Transp.-Prot. Cover									NOT APPLICABLE														
54	- Racks/Rack Set/Floor Assy,Trans-PC		WHEN TRANSPORTERS ARE NOT IN USE,																		1*	-	-	-
55	- Transp.Trailer-Protective Cover		THESE PROTECTIVE COVERS WILL BE USED.																		1	1	-	-
56	Transducer/Gauge Calib. Kit		X		X					X	X	X			X				X		1	1	1	-

*Caravaned Items

Table 5.2-5. Concepts VII and VIII Ground Support Equipment Requirements (Cont)

CONCEPT VII & VIII			
OWNER		INTEG. SITE	
IGLOO*	P	EXPMT EQUIP	SL
LS / LS	IC / U	IC / U	LS / LS

*SUPPORT SYSTEMS IGLOO & EQUIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION (P/IGL)	3.0 CONNECT & C/O IGL/ORB SIMULATOR SET	4.0 EXPERIMENT C/O & INTEGRATION	5.0 GSE DISCONNECT	6.0 PALLET/IGLOO SHIPMENT	7.0 P/IGL & PSS EQUIP ARRIVAL & R/I	8.0 MATE PALLET/IGLOO (SUPPORT SYSTEMS)	9.0 SPACELAB INTEGRATION	10.0 ORBITER CARGO INTEGRATION	11.0 LAUNCH OPERATIONS	12.0 MISSION OPERATIONS (REF)	13.0 POST FLIGHT OPERATIONS	14.0 REFURBISH SUPPORT SYSTEMS IGLOO	15.0 PALLET/IGLOO SHIPMENT	16.0 REMOVE EXPMTS/EQUIP FROM P/IGL	17.0 EXPERIMENT SHIPMENT	18.0 REFURB/RECONFIGURE PALLET & IGLOOS	19.0 POST REFURB PALLET/IGLOO SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC(VII)/U(VIII)	ACTIVE LS(VII & VIII)	ACTIVE	SPARES IC(VII)/U(VIII)	SPARES LS(VII & VIII)	SPARES
	ESRO-SUPPLIED																									
	AUXILIARY (Cont'd.)																									
57	Interior Protective Devices									NOT APPLICABLE																
58	SM/EM Hatch/Seal Protective Covers									NOT APPLICABLE																
59	SM Hatch Cover & Seal									NOT APPLICABLE																
	SERVICING																									
60	Ground Servicing & Cooling Unit			X	X					X	X				X				X		1	1		1	1	
61	GO_2 Transfer & Servicing Unit									X	X	X		X							-	1		-	1	
62	GN_2 Transfer & Servicing Unit									X	X	X		X							-	1		-	1	
63	Freon Transfer & Servicing Unit			X	X					X											1	1		-	-	
64	Vacuum Servicing Unit				X					X	X			X	X				X		1	1		-	-	
65	O_2/N_2 Pressure Unit									X	X	X		X							-	1		-	-	

Table 5.2-5. Concepts VII and VIII Ground Support Equipment Requirements (Cont)

CONCEPT VII & VIII				
OWNER			INTEG. SITE	
IGLOO*	P	EXPMT EQUIP	SL	
LS / LS	IC / U	IC / U	LS / LS	

*SUPPORT SYSTEMS IGLOO & EQUIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION (P/IGL)	3.0 CONNECT & C/O IGL/ORB SIMULATOR SET	4.0 EXPERIMENT C/O & INTEGRATION	5.0 GSE DISCONNECT	6.0 PALLET/IGLOO SHIPMENT	7.0 P/IGL & PSS EQUIP ARRIVAL & R/I	8.0 MATE PALLET/IGLOO (SUPPORT SYSTEMS)	9.0 SPACELAB INTEGRATION	10.0 ORBITER CARGO INTEGRATION	11.0 LAUNCH OPERATIONS	12.0 MISSION OPERATIONS (REF)	13.0 POST FLIGHT OPERATIONS	14.0 REFURBISH SUPPORT SYSTEMS IGLOO	15.0 PALLET/IGLOO SHIPMENT	16.0 REMOVE EXPMTS/EQUIP FROM P/IGL	17.0 EXPERIMENT SHIPMENT	18.0 REFURB/RECONFIGURE PALLET & IGLOOS	19.0 POST REFURB PALLET/IGLOO SHIPMENT	ACTIVE IC(VII)/U(VIII)	ACTIVE LS(VII & VIII)	SPARES IC(VII)/U(VIII)	SPARES LS(VII & VIII)
	NASA-SUPPLIED																							
	HANDLING																							
1	Weight & Balance Sling									X											-	1	-	-
2	Alignment Kit		X		X				X		X										1	1	1	1
3	Cargo Lift Trailer						X									X					1	1	-	-
4	Air Transp. Tie Down Kit (C-5A)						X									X					1*	-	-	-
5	Mobile Hoist/Sling		X											X	X				X		1	1	-	-
6	Small Equip. Xport Carts		X	X	X	X				X	X			X	X				X		5	5	-	-
7	Spacelab Shipping Canister (747)						X									X					1*	-	-	-
8	Spacelab Shipping Canister Sling						X									X					1*	-	-	-
	CHECKOUT																							
9	EMI Test Equipment				X					X	X										1	1	-	-
10	Electrical Load Banks										X										-	1	-	-
11	Optical Measurement Unit									X											-	1	-	-
	AUXILIARY																							
12	Battery Activity Unit										X										-	1	-	1
13	Clean Enclosure (10K Portable)																				-	2	-	-
	Weight & Balance Kit																							
14	- Weight & Bal. Meas. Equip.									X											-	1	-	1

*Caravaned Items

Table 5.2-5. Concepts VII and VIII Ground Support Equipment Requirements (Cont)

CONCEPT VII & VIII			
OWNER		INTEG. SITE	
IGLOO*	P	EXPMT EQUIP	SL
LS / LS	IC / U	IC / U	LS / LS

*SUPPORT SYSTEMS IGLOO & EQUIPMENT

LINE ITEM	GSE NOMENCLATURE	1.0 EXPERIMENT SHIPMENT	2.0 EXPERIMENT INSTALLATION (P/IGL)	3.0 CONNECT & C/O IGL/ORB SIMULATOR SET	4.0 EXPERIMENT C/O & INTEGRATION	5.0 GSE DISCONNECT	6.0 PALLET/IGLOO SHIPMENT	7.0 P/IGL & PSS EQUIP ARRIVAL & R/I	8.0 MATE PALLET/IGLOO (SUPPORT SYSTEMS)	9.0 SPACELAB INTEGRATION	10.0 ORBITER CARGO INTEGRATION	11.0 LAUNCH OPERATIONS	12.0 MISSION OPERATIONS (REF)	13.0 POST FLIGHT OPERATIONS	14.0 REFURBISH SUPPORT SYSTEMS IGLOO	15.0 PALLET/IGLOO SHIPMENT	16.0 REMOVE EXPMTS/EQUIP FROM P/IGL	17.0 EXPERIMENT SHIPMENT	18.0 REFURB/RECONFIGURE PALLET & IGLOOS	19.0 POST REFURB PALLET/IGLOO SHIPMENT	QUANTITY REQUIREMENTS ACTIVE IC(VII)/U(VIII)	ACTIVE LS(VII & VIII)	SPARES IC(VII)/U(VIII)	SPARES LS(VII & VIII)
	NASA-SUPPLIED																							
	AUXILIARY (Cont'd.)																							
15	Structural Repair Kit		X	X						X	X				X				X		1	1	-	-
16	Cleaning Kit		X	X			X		X	X	X				X				X		1	1	-	-
17	Transp. Instrumentation Kit						X									X					1*	-	-	-
18	Flow Rate Test Set			X	X					X					X				X		1	1	-	-
19	Leak Detector/MMS Spectrometer			X	X					X	X	X		X	X				X		1	1	1	1
20	X-Ray Unit		X							X	X				X				X		1	1	-	-
21	Install. Tool Kit (Gask-O-Seal)		X						X						X				X		1	1	-	-
22	SL Safing Equipment Set													X							-	1	-	-
23	General Purpose Lab Equip. Set			X	X					X	X	X			X				X		1	1	-	-
24	Ground Air Cond. Unit (Personnel)									NOT APPLICABLE														
	SERVICING																							
25	Trace Gas Servicer			X	X					X	X	X		X	X				X		1	1	-	-
26	Cryogenic Servicing Unit											X									-	1	-	-
27	Hypergolic Servicing Units											X		X							-	1	-	-

*Caravaned Item

Space Division
Rockwell International

2. Handling. Equipment used to move, position, or handle the Spacelab modules or other equipment (e.g., slings/hoists, dollies and transporters).

3. Auxiliary. Equipment that is necessary for conducting a given test, but which may have a universal application (e.g, vacuum pumps, cooling carts).

4. Servicing. Equipment used to service the Spacelab or its elements (e.g., Freon, water servicing of the coolant loops).

GSE DESCRIPTION

An integral part of the identification of GSE requirements is a definition of each GSE item; a three-word title can be misleading. Also, the ESRO/ERNO list of supplied GSE is not firm at this time. Therefore, in order to clarify the assumptions regarding GSE supplied with the Spacelab, the definitions are subdivided into ESRO and NASA equipment lists.

ESRO-Supplied GSE

The equipment supplied by this organization, either stated or implied in the "Spacelab Payload Accommodation Handbook," dated October 1974, is grouped in the various equipment categories defined above.

Handling Equipment

Interior Access Kit - Comprised of a contingency entry kit for vertical access to the Spacelab while at the pad, and a horizontal entry kit after loading of the Spacelab into the Orbiter at the OPF. The design concepts for both types of entry are shown in Figures 5.2-1 and 5.2-2.

Exterior Access Kit - Contains scaffolding and auxiliary pallet floor panels to obtain access to the Spacelab during checkout. Figure 5.2-3 illustrates this equipment.

Sling Assembly Kits - Consists of sling kits for handling virtually all major Spacelab elements. The individual sling kits that make up the sling assembly kits are listed in Tables 5.2-1 through 5.2-5.

Storage Fixtures - Provides the capability or means for storing the major Spacelab elements during periods of inactivity while awaiting assembly. The main items include: experiment module storage fixture, support module storage fixture, pallet storage fixture, and rack/rack set/floor assembly storage fixture.

Main Assembly Stand - Used for buildup and integration of the various Spacelab configurations. Figure 5.2-4 shows the main assembly stand and its matched rail system.

- Entry is from above through orbiter, down through the Spacelab tunnel and into the modules
- The segmented tunnel access kit is progressively lowered and attached
- Telescoping extension ladder is positively guided into module, using tunnel access kit fittings
- Personnel and equipment are tethered for safety
- Emergency breathing air provided by back pack
- Forced air circulation throught utility tray duct
- Dolly carries tools using ladder-mounted track guides
- Visual contact with a safety observer is maintained at all times
- A portable winch assists in lowering equipment and personnel

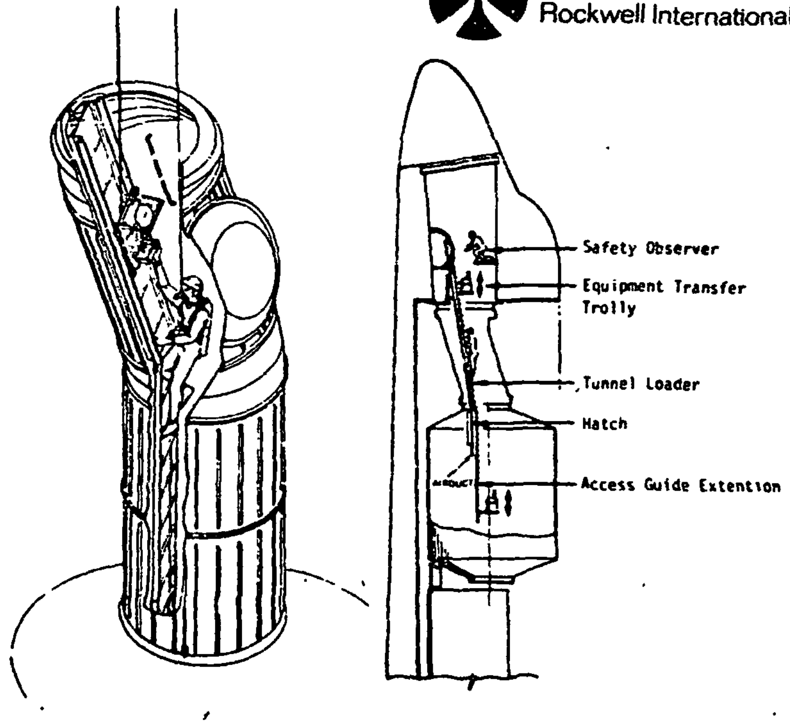

Figure 5.2-1. Contingency Vertical Entry

- Semi-circular utility tray
- Removable walkway panels
- Equipment transfer dolly
- Segmented for varying tunnel configurations
- Incorporates electrical outlets for ground illumination
- Auxiliary panels protect Spacelab interior
- Accommodates contingency vertical access kits

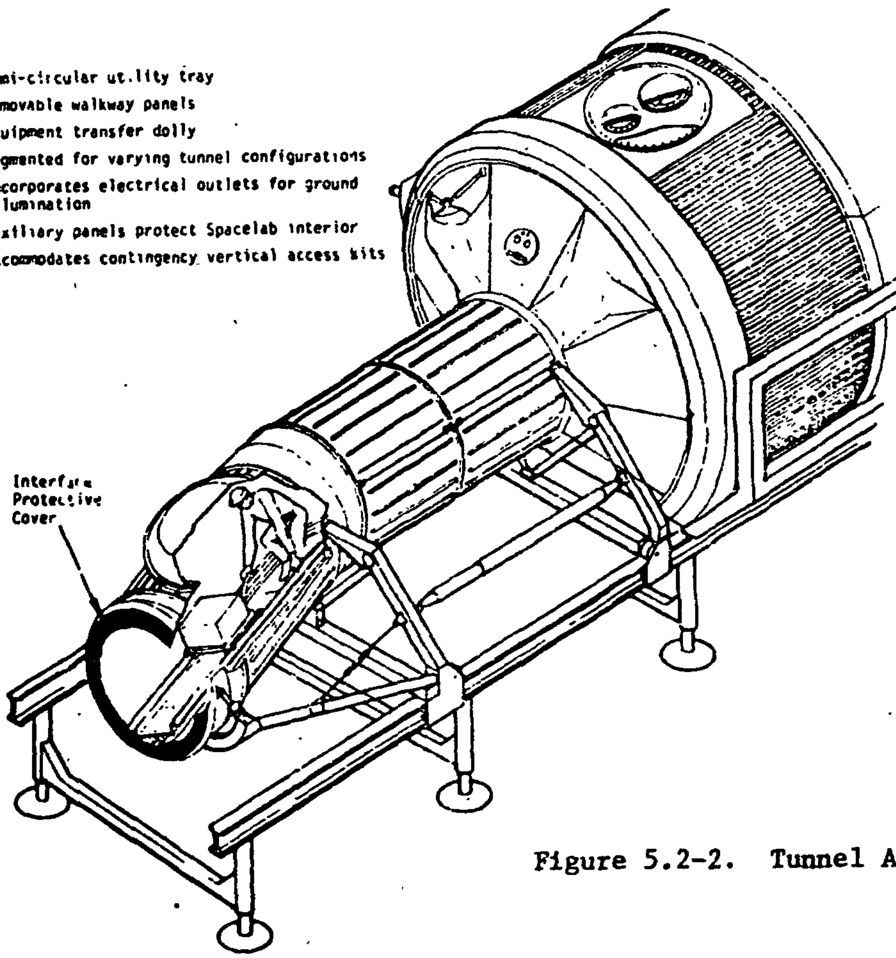

Figure 5.2-2. Tunnel Access Kit

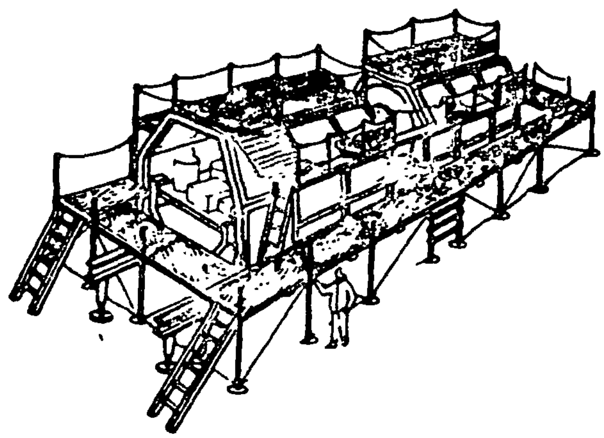

Figure 5.2-3. Exterior Access Kit

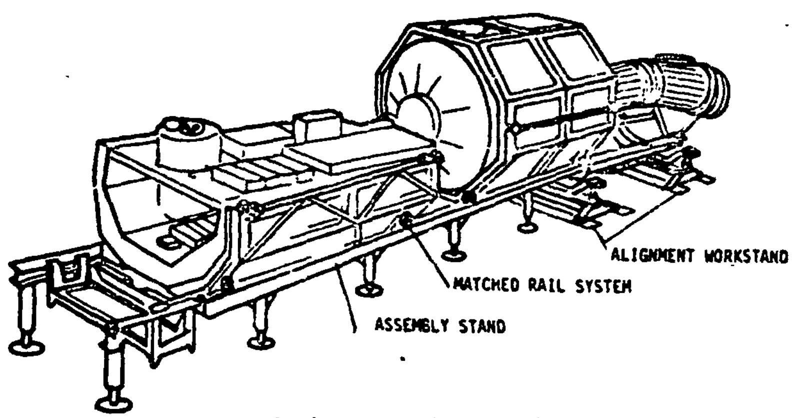

Figure 5.2-4. Matched Rail Assembly Stand

Alignment Work Stand - Used in conjunction with the main assembly stand. It provides a mechanical method of aligning the various Spacelab elements for assembly. Figure 5.2-4 illustrates how the alignment work stand is utilized.

Aft End Cone Stand - Provides a temporary stowage device for the aft bulkhead to prevent damage to the unit prior to its installation on the rack/pallet assembly.

End Cone Support - Allows for tilting of the aft end cone for C-5A transport, for concepts that could utilize this transportation mode, and permits adjustments for mating the end cone to the module. Figure 5.2-5 shows the end cone support usage.

Rack and Floor Rail Set - Facilitates installation of the rack/floor. The device works in conjunction with the alignment work stand during insertion of the rack/floor assembly into the SM/EM structural shells. Figure 5.2-5 illustrates the functional utilization of this equipment.

Transporters - Utilized to transport the Spacelab elements over surface roads joining facilities at a given site. Such transportation is to be accomplished with the Spacelab elements enclosed in an environmentally controlled container. The main items of equipment considered in the transporter category are: module transporter platform, end cone transporter platform, and transport trailer. The rack set/floor platform also accommodates the pallet.

Checkout Equipment

Data Processing Equipment - Illustrated in Figure 5.2-6; consists of the following units.

- Recording and Timing Unit

  Time base
  Time code generator
  Analog tape recorders
  Tape search unit
  Strip chart recorder

- Interface Units

  PCM decomutator and digital/analog converters
  Command and data management subsystem (CDMS) interfaces
  Measuring and stimuli interfaces
  Switch matrix
  Patch panel
  PCM simulator

- Computer Peripherals

  Teletypewriter
  Line printer
  Magnetic tapes
  Dual disk storage
  Paper tape reader/punch

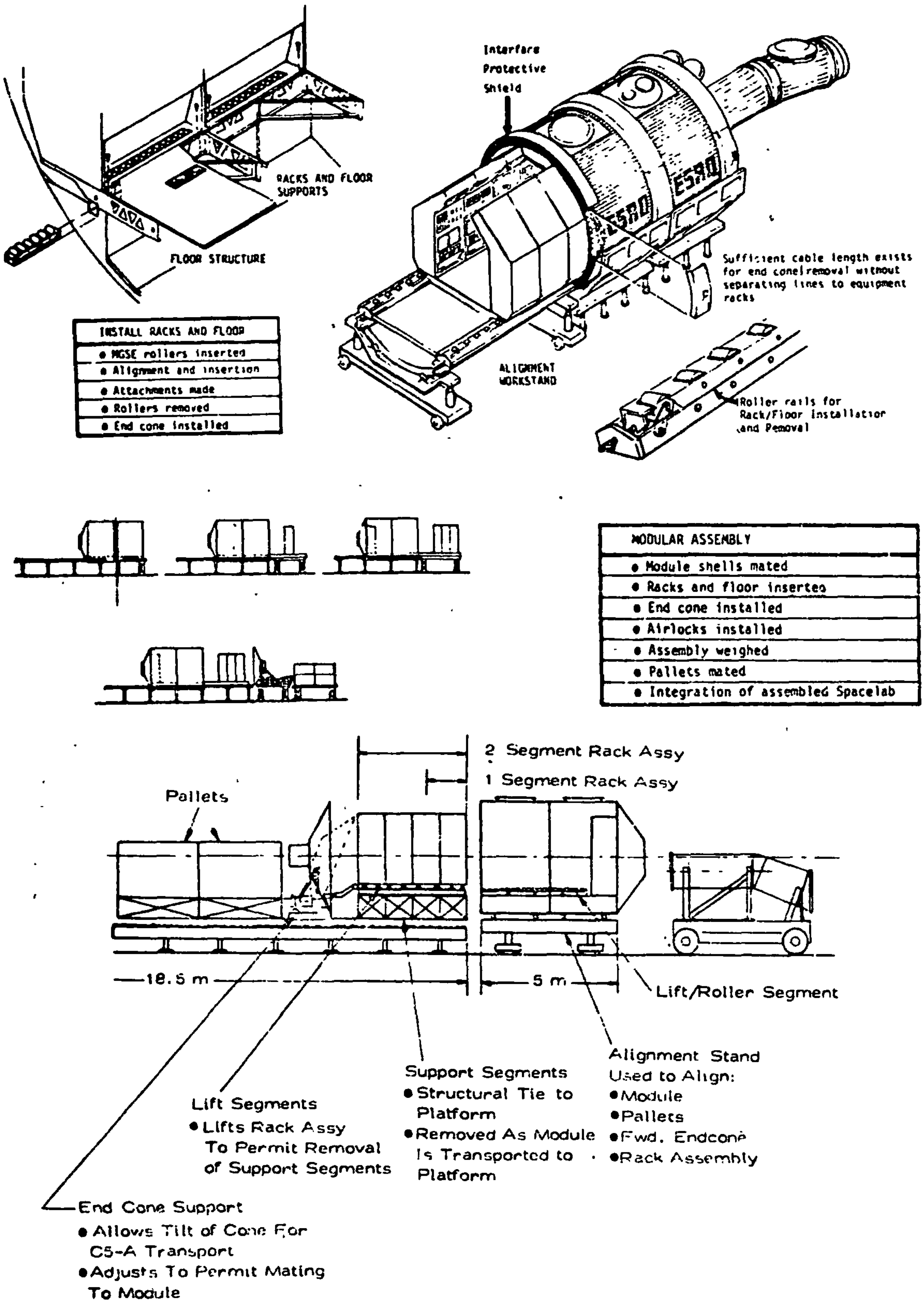

Figure 5.2-5. Integrated Experiment Group Installation

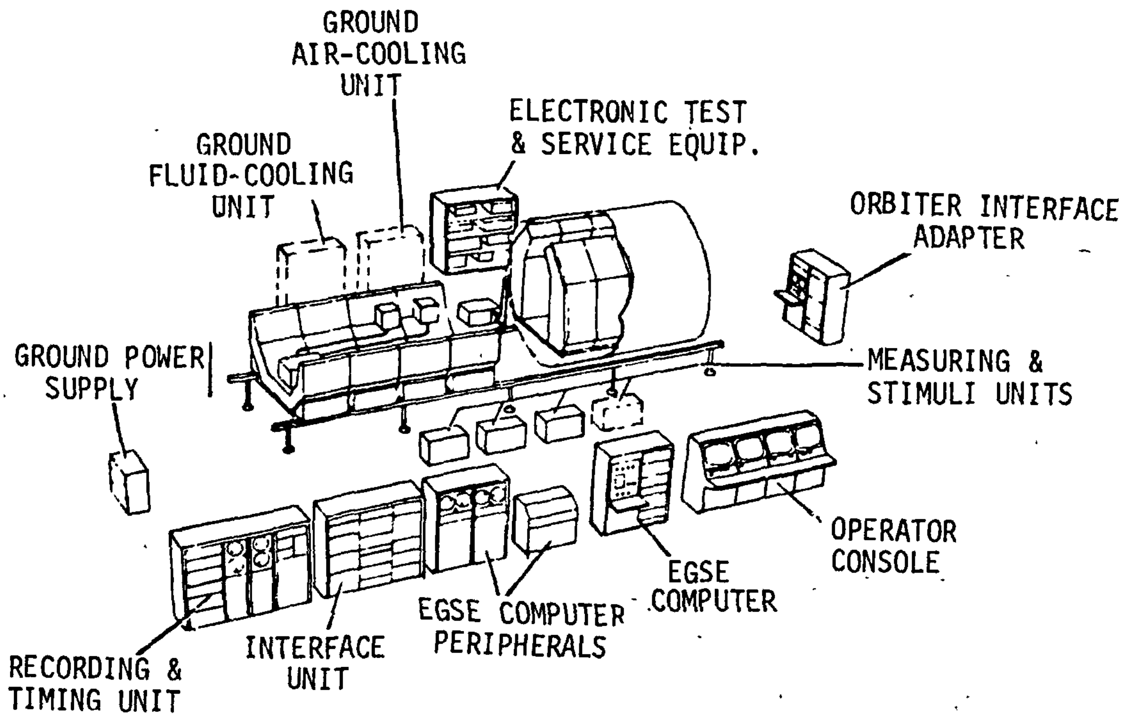

Figure 5.2-6. EGSE Assemblies

- Computer

  Processor
  Memory
  Input/output

- Operator Console

  CRT and keyboard
  Subsystem computer CRT and keyboard
  Experiment computer CRT and keyboard
  Caution and warning display
  CCTV monitor
  Intercommunications
  Quick-look data display
  Status displays
  Time displays
  Dedicated controls and displays
  Alarms

- Measuring and Stimuli Units

  Analog/digital converters
  Digital/analog converters
  Multiplexer
  Demultiplexer
  Transmitter/receiver

Ground Power Supply - Supplies 28 V dc and control and distribution to the Spacelab during Level III tests.

Electrical Power Test Set - Used to verify power levels, regulation, voltage and amperage of Spacelab power sources.

Simulators - Includes a support module simulator and Orbiter interface simulator.

Support Module Simulator. Utilized during experiment integration to reduce the system "ON" time of the flight support module, and supplies the following functions to the experiments/racks: ac/dc regulated power, control and display, caution and warning, analog/video data, CCTV, intercom, data bus, and experiment processor.

Orbiter Interface Simulator. Provides functions normally supplied by the Orbiter which are necessary for an evaluation of Spacelab subsystem or experiment equipment performance. The Orbiter simulator provides the following: fuel cell power and distribution simulation, Spacelab signal terminations, Orbiter signal simulations, payload specialist station (PSS) equipment inputs, and umbilical interface.

Control and Data Acquisition Console - Used to control the GSE computer and peripherals, recording/timing unit, and the interface unit with the CDMS.

Cable Kits - Interconnect the electronic test and service equipment and flight hardware. Include the following: ground test remote site cable kit, launch support (vertical) cable kit, subsystem test cable kit, experiment test cable kit, prelaunch servicing cable kit, recovery cable kit, electrical system test cable kit, and GSE/facility cable kit.

Memory Load and Verify Unit - Provides a method for loading Spacelab computer memory and verification of loaded data.

ECLSS Test Unit - Monitors and checks the operation of components and subsystems of the ECLSS.

Continuity Test Equipment - Used to perform continuity/resistance tests of Spacelab cabling.

Spacelab Module Universal Seal Test Console - Provides the capability for pressurizing and monitoring pressure decay of Spacelab enclosures.

Auxiliary Equipment

Lighting Kit - Provides illumination of the Spacelab interior and exterior during test and maintenance.

Ground Air-Cooling Unit (Equipment) - Provides cooling air to the Spacelab electronic equipment through the racks and equipment coldplates and fins.

Environmental Control Kit (Transport/Storage) - Maintains 100K cleanliness level during transport or storage of the Spacelab or its major elements. It is comprised of the following soft covers: module environmental soft cover, rack/pallet environmental soft cover, utility bridge environmental soft cover, pallet environmental soft cover, and end cone (bulkhead) environmental soft cover.

Protective Cover Kits - Provides protection to Spacelab transport equipment against inclement weater, dust and dirt. The cover kits are made up of the following: module transporter protective cover, end cone transporter protective cover, racks/rack set/floor assembly transporter protective cover, and transporter trailer protective cover.

Transducer/Gauge Calibration Kit - Used for calibration/certification of all transducers and gauge instrumentation used during test and operations.

Interior Protective Devices - Utilized in the Spacelab interior to cover Spacelab components (e.g., consoles, experiments, and racks) which are susceptible to personnel damage during test/operations requiring personnel in the Spacelab.

SM/EM Hatch/Seal Protective Covers - Protects the matched mating surfaces and seals the SM/EM hatch openings during operations when these surfaces are exposed.

SM Hatch Cover and Seal - Provides a structural closeout hatch and seal capable of supporting pressure forces during Spacelab pressure-decay leak checks. This device will act as a closeout hatch during shipment to reduce contamination of the Spacelab interior.

Servicing Equipment

Ground Servicing and Cooling Unit - Provides Spacelab coolant-loop servicing and acts as a heat sink for Spacelab coolant-loop heat exchange from electrical/electronic equipment. This unit controls flow rate and coolant-loop fluid temperatures to maintain equipment temperatures at design-operating levels.

Gaseous Oxygen Transfer and Servicing Unit - Transfers GO_2 to Spacelab ECLSS for use in the air revitalization system which supplies a breathing atmosphere to the crew.

Gaseous Nitrogen Transfer and Servicing Unit - Transfers GN_2 to the Spacelab ECLSS for use in the air revitalization system supplying breathing air to the crew.

Freon Transfer and Servicing Unit - Used to transfer and service Freon to the pallet coolant loop of the Spacelab heat exchanger. The unit would be used in conjunction with the ground servicing and cooling unit to provide the complete Freon/water Spacelab coolant loop during ground operations.

Vacuum Servicing Unit - Evacuates the gas storage systems of the Spacelab. If cryogens are used in any Spacelab payload configurations, this device can be used to evacuate cryogenic gases.

O_2/N_2 Pressure Unit - Performs complete functional tests of components and subassemblies of the ECLSS.

NASA-Supplied GSE

The equipment assumed to be supplied by NASA is defined by category in the same way as for ESRO-supplied equipment. The selection criteria for the assumption of NASA-supplied equipment were based upon the uniqueness of the item. That is, Spacelab GSE that is usable with the Spacelab-only was assumed to be provided by ESRO; general-support GSE was provided by NASA. Some of the NASA-supplied GSE may be obtained by modifying equipment that is currently in the NASA equipment inventory.

Handling Equipment

Weight-and-Balance Sling - Used to lift and rotate the Spacelab, or its elements, during weight-and-balance operations.

Alignment Kit - Consists of optical device(s) used for various levels of alignment verification of experiment equipment and Spacelab structure.

Cargo Lift Trailer - Used to offload the Spacelab or its elements when the C-5A aircraft shipping mode is employed.

Air Transport Tiedown Kit - Required for securing the Spacelab and its shipping pallet in the C-5A during transportation.

Mobile Hoist/Sling - Provides lifting of equipment too large for personnel, but small enough to not warrant overhead crane equipment.

Small Equipment Transport Carts - Consists of handcarts to move small electrical/mechanical components too large for personnel handling.

Spacelab Shipping Canister - Used for piggyback shipment modes with the 747 aircraft. An aerodynamic and structurally designed shipping canister is used for shipment of Spacelab modules.

Spacelab Shipping Canister Sling - Consists of a lifting sling for loading and offloading the Spacelab shipping canister.

Checkout Equipment

Electromagnetic Interference (EMI) Test Equipment - Consists of various items of electronic equipment required to determine the EMC between experiments, Spacelab, and/or Orbiter systems.

Electrical Load Banks - Provides simulated loads of flight hardware for verification of power levels and battery loads during activation.

Optical Measurement Unit - Provides a means to check the optical properties of the Spacelab exterior surfaces to determine its radiation characteristics.

Auxiliary Equipment

Battery Activity Unit - Provides a means for activating, monitoring and conditioning Spacelab batteries.

Clean Enclosure (10,000 Level) - Provides a portable plastic clean room for Spacelab payload processing operations where cleanliness levels (10,000 class) are not provided in the basic facility design.

Weight-and-Balance Kit - Includes all weight and balance measuring equipment such as load cells, indicators, and signal conditioning electronics necessary to perform weight and balance operations of the Spacelab or its elements.

Structural Repair Kit - Includes all equipment required to accomplish minor Spacelab structural repairs. For example, the kit probably would include items like heat lamps/guns, solvents, bonding materials, clamps, buffers, vacuum equipment, and protective surface preparations such as alodining materials. Manufacturing jigs and fixtures are specifically excluded from this type of equipment.

Cleaning Kit - Consists of vacuum devices for cleaning Spacelab interior and exterior.

Transportation Instrumentation Kit - Provides recording instrumentation equipment to measure maximum g-loads and direction imposed by transportation shock. For air transportation (which is the primary mode suggested for the Spacelab), temperature, pressure and possibly humidity, are additional parameters that would be recorded.

Flow Rate Test Set - Used to apply, measure and monitor static and dynamic pressures at various fluid flow rates.

Leak Detector/Mass Spectrometer - Provides rapid means of detecting leakage of Spacelab systems.

X-Ray Unit - Used to verify integrity of structural and mechanical elements; e.g., weld cracks and inclusions.

Installation Tool Kit (GASK-O-SEAL)- Used to install seals on various Spacelab equipment items.

Spacelab Safing Equipment - Consists of ordnance and emergency vent safing devices (e.g., pyro shorting plugs), used to ensure personnel and equipment safety prior to launch and after Orbiter landing.

General-Purpose Laboratory Equipment - Consists of various hand-held or portable mechanical or electronic equipment items used during checkout operations such as meters, scopes, signal generators, gauges, valves, etc.

Ground Air-Conditioning Unit - Provides conditioned air to interior of the Spacelab for control of interior temperature, humidity, and cleanliness during periods of Level II test and integration.

Servicing Equipment

Trace Gas Servicer - Required to provide trace gas servicing of leak detection devices; e.g., helium trace gas for a helium mass spectrometer.

Cryogenic Servicing Units - Used to filter, sub-cool, and transfer cryogenic liquids to experiment equipment (currently defined ATL payloads do not require this function).

Hypergolic Servicing Units - Provides service/de-service of hypergolic fuels to experiment equipment (currently defined ATL payloads do not require this function).

SUMMARY OF REQUIRED GSE ITEMS

The detailed GSE requirements were presented in Tables 5.2-1 through 5.2-5. As an aid in the assessment of these data, variations between concepts in GSE requirements and total quantities of GSE required are presented below.

Concept-Dependent GSE Requirements

An evaluation of the data in Tables 5.2-1 through 5.2-5 was conducted to identify the variations in GSE requirements between concepts. The total number of each GSE item required by each concept was the key parameter. Ownership/location changes of a GSE item between concepts was not considered significant. Only variations in the total required end items of a particular GSE item was considered to be a potential factor in the evaluation of the processing concepts.

Tables 5.2-6 and 5.2-7 (complete Spacelab and pallet-only, respectively) summarize those items of GSE that will be required in varying quantities as a function of the processing concept. The required quantity of all other GSE items is the same regardless of the processing concept.

In the case of the complete Spacelab processing concepts, there are two primary factors that cause the variation of required quantities of GSE: (1) checkout equipment requirements are greater in those concepts (II, III, IV) where Level III integration occurs at one site (user or IC), and Level II integration occurs at another site (LS); and (2) requirements for handling, auxiliary, and servicing equipment are maximum in Concept III where three centers are involved in the processing of the Spacelab hardware.

In the case of the pallet-only processing concepts the variation in quantities is entirely due to the additional equipment required to process the Spacelab hardware at three sites in Concept VI.

Table 5.2-6. Concept-Dependent GSE Requirements - Complete Spacelab Processing

LINE ITEM*	NOMENCLATURE / CONCEPT / CENTER	I (IC) & V (U) IC/U	I (IC) & V (U) LS	I (IC) & V (U) TOTAL	II (IC) & IV (U) IC/U	II (IC) & IV (U) LS	II (IC) & IV (U) TOTAL	III IC	III U	III LS	III TOTAL
	ESRO-SUPPLIED										
3	SCAFFOLDING (ESRO COMM TYPE)	1	2	3	1	2	3	1	1	2	4
5	END CONE SLING SET	1	-	1	1	-	1	1	1	-	2
7	HORIZONTAL SLING KIT	1	1	2	1	1	2	1	1	1	3
9	UPPER HANDLING CAGE - MODULE	1	1	2	-	1	1	-	-	1	1
10	LOWER HANDLING CAGE - MODULE	1	1	2	-	1	1	-	-	1	1
11	UPPER HANDLING CAGE - PALLET	1	1	2	1	1	2	1	1	1	3
12	HANDLING PLATFORM - PALLET	1	1	2	1	1	2	1	1	1	3
13	UTILITY BRIDGE HANDLING KIT	1	-	1	1	-	1	1	1	-	2
18	MAIN ASSEMBLY STAND	1	2	3	1	2	3	1	1	2	4
20	AFT END CONE STAND	1	-	1	1	-	1	1	1	-	2
21	END CONE SUPPORT	1	-	1	1	-	1	1	1	-	2
26	TRANSPORT TRAILER	1	1	2	1	1	2	1	1	1	3
27	DATA PROCESSOR	1	-	1	1	1	2	-	1	1	2
28	GROUND POWER SUPPLY	1	-	1	1	1	2	-	1	1	2
29	ELECTRICAL POWER TEST SET	1	-	1	1	1	2	-	1	1	2
32	CONTROL & DATA ACQ. CONSOLE	1	-	1	1	1	2	-	1	1	2
39	ELEC SYST TEST CABLE KIT	1	1	2	-	1	1	-	-	1	1
41	MEMORY LOAD & VERIFY UNIT	1	-	1	1	1	2	-	-	1	1
44	SPACELAB MODULE UNIVERSAL SEAL TEST CONSOLE	1	1	2	-	1	1	-	-	1	1
46	GND AIR-COOLING UNIT (EQUIP)	1	-	1	1	1	2	-	1	1	2
55	TRANSPORT TRAILER PROTEC. COVER	1	1	2	1	1	2	1	1	1	3
56	TRANSDUCER/GAUGE CALIB KIT	1	1	2	1	1	2	1	1	1	3
60	GND SERVICING & COOLING UNIT	1	1	2	1	1	2	1	1	1	3
61	GO_2 TRANSFER & SERVICING UNIT	1	1	2	-	1	1	-	-	1	1
62	GN_2 TRANSFER & SERVICING UNIT	1	1	2	-	1	1	-	-	1	1
63	FREON TRANSFER & SERV UNIT	1	1	2	1	1	2	1	1	1	3
64	VACUUM SERVICING UNIT	1	1	2	1	1	2	1	1	1	3
65	O_2/N_2 PRESSURE UNIT	1	1	2	-	1	1	-	-	1	1
	NASA-SUPPLIED										
2	ALIGNMENT KIT	1	1	2	1	1	2	1	1	1	3
3	CARGO LIFT TRAILER	1	1	2	1	1	2	1	1	1	3
5	MOBILE HOIST/SLING	1	-	1	1	1	2	1	1	1	3
6	SMALL EQUIPMENT CARTS	5	5	10	5	5	10	5	5	5	15
15	STRUCTURAL REPAIR KIT	1	1	2	1	1	2	1	1	1	3
16	CLEANING KIT	1	1	2	1	1	2	1	1	1	3
18	FLOW RATE TEST SET	1	-	1	1	1	2	1	1	1	3
19	LEAK DETECTOR/MMS SPECTROM	1	1	2	1	1	2	1	1	1	3
20	X-RAY UNIT	1	-	1	1	1	2	1	1	1	3
21	INSTALLATION TOOL KIT (GASK-O-SEAL)	1	-	1	1	1	2	1	1	1	3
23	GENERAL-PURPOSE LAB EQUIP SET	1	1	2	1	1	2	1	1	1	3
24	GROUND AIR-CONDITIONING UNIT (PERSONNEL)	1	1	2	-	1	1	-	-	1	1
25	TRACE GAS SERVICER	1	1	2	1	1	2	1	1	1	3

*LINE ITEMS AS REFERENCED IN TABLES 5.2-1 THROUGH 5.2-5

Table 5.2-7. Concept-Dependent GSE Requirements
Pallet-Only Spacelab Processing

LINE ITEM*	NOMENCLATURE	CONCEPT	VI				VII (IC) & VIII (U)		
		CENTER	IC	U	LS	TOTAL	IC/U	LS	TOTAL
	ESRO-SUPPLIED								
7	HORIZONTAL SLING KIT		1	1	1	3	1	1	2
11	UPPER HANDLING CAGE - PALLET		1	1	1	3	1	1	2
12	HANDLING PLATFORM - PALLET		1	1	1	3	1	1	2
26	TRANSPORT TRAILER		1	1	1	3	1	1	2
56	TRANSDUCER/GAGE CALIB KIT		-	1	1	2	-	1	1
60	GND SERVICING & COOLING KIT		1	1	1	3	1	1	2
63	FREON TRANSFER & SERVICING UNIT		1	1	1	3	1	1	2
64	VACUUM SERVICING UNIT		1	1	1	3	1	1	2
	NASA-SUPPLIED								
3	CARGO LIFT TRAILER		1	1	1	3	1	1	2
5	MOBILE HOIST/SLING		1	1	1	3	1	1	2
6	SMALL EQUIP TRANSPORT CARTS		5	5	5	15	5	5	10
15	STRUCTURAL REPAIR KIT		1	1	1	3	1	1	2
16	CLEANING KIT		1	1	1	3	1	1	2
18	FLOW RATE TEST SET		1	1	1	3	1	1	2
19	LEAK DETECTOR/MMS SPECTROMETER		1	1	1	3	1	1	2
20	X-RAY UNIT		1	1	1	3	1	1	2
21	INSTALLATION TOOL KIT (GASK-O-SEAL)		1	1	1	3	1	1	2
23	GENERAL-PURPOSE LAB EQUIP SET		1	1	1	3	1	1	2
25	TRACE GAS SERVICER		1	1	1	3	1	1	2

*LINE ITEMS AS REFERENCED IN TABLES 5.2-1 THROUGH 5.2-5

GSE Requirement Summary by Concept

GSE end item (E/I) requirements for all eight processing concepts are presented in summation "trees" in Figures 5.2-7 through 5.2-11. The first summary level (Σ Level ①) of the tables indicates the ESRO-supplied quantities of GSE by site, concept, category (handling, checkout, etc.), and E/I status (active or spare). The second (Σ Level ②) presents similar data for NASA-supplied GSE end items. The next level (Σ Level ③) provides summaries of GSE end items (without regard to supplier) by site, concept, category, and status. Level four (Σ Level ④) shows summaries of GSE end items (without regard to supplier or status) by site, concept, and category. The fifth level (Σ Level ⑤) indicates GSE E/I summaries (without regard to supplier, status or site) by concept and category. The final level (Σ Level ⑥) summarizes the GSE E/I requirements for the total program by concept. It should be noted that similarity of Concepts I/V, II/IV, and VII/VIII results in a single table each for displaying quantity requirements. Only the cognizant center changes. In Concept I, the GSE is at the IC and LS; in Concept V, the GSE is at the user's site and LS. The same interchange of GSE site location occurs between Concepts II and IV, and VII and VIII.

Table 5.2-8 summarizes the GSE requirements by concept. The significantly larger number of GSE items required in Concept III (complete Spacelab) and Concept VI (pallet-only), as compared to the other concepts for a comparable Spacelab configuration, is due to the requirement to process the flight hardware at three sites in these two concepts. In all other cases, only two sites are involved. The difference in the GSE requirements for the processing of the two ATL Spacelab configurations (complete Spacelab and pallet-only) is primarily due to the required handling and transporting of the SM/EM and racks of the complete Spacelab configuration.

An evaluation of the commonality of GSE required for processing both Spacelab configurations indicated that with the exception of two items, the complement of GSE to process the complete Spacelab can also accommodate the processing of the pallet-only Spacelab. The two pallet-only unique GSE items are: (1) an Orbiter payload specialist station simulator at the Level III integration site, and (2) support systems igloo handling equipment at the launch site. Thus, adding only two items to the complete Spacelab GSE lists will permit intermixing of the two Spacelab configurations in Concepts II, III, and IV.

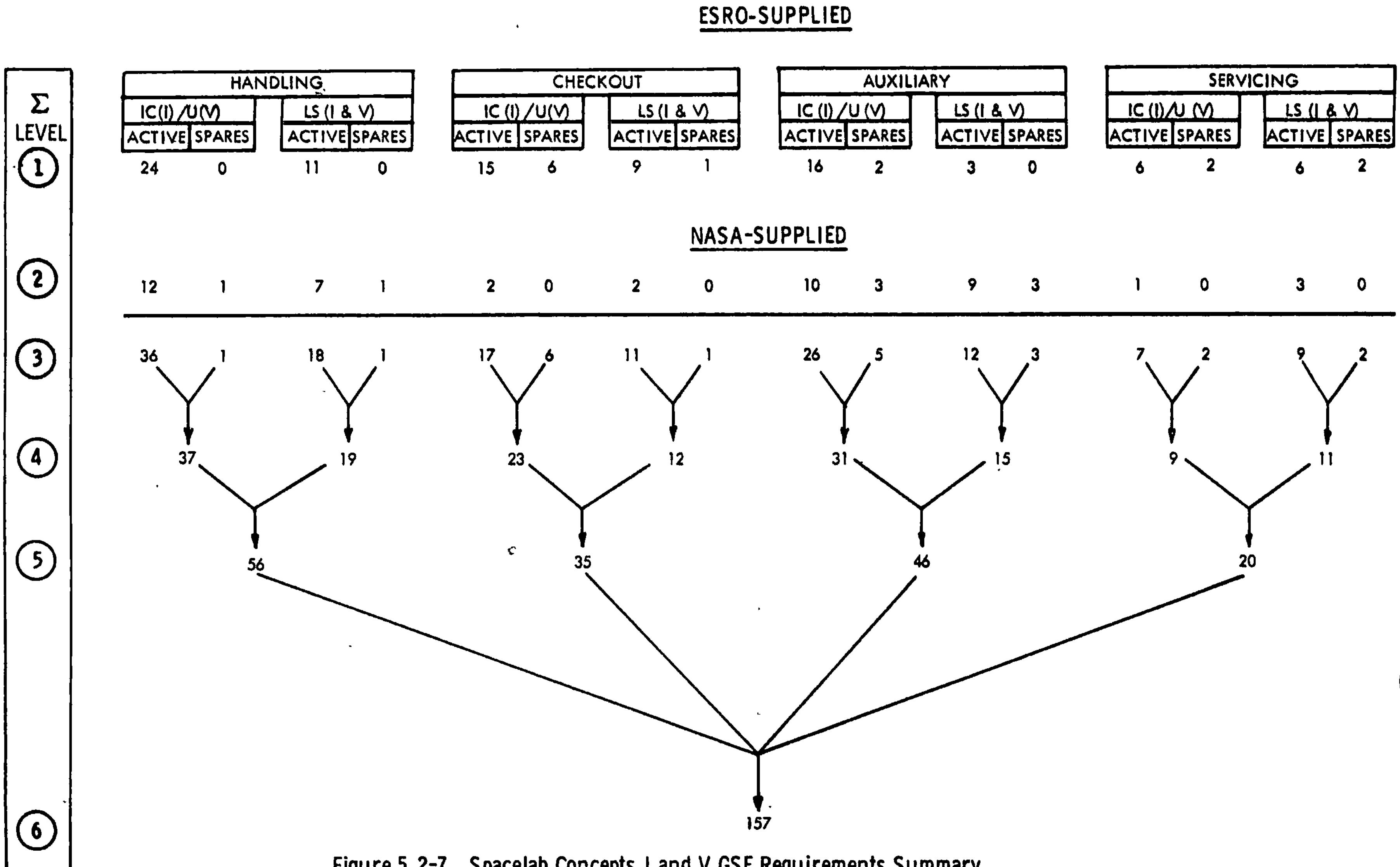

Figure 5.2-7. Spacelab Concepts I and V GSE Requirements Summary

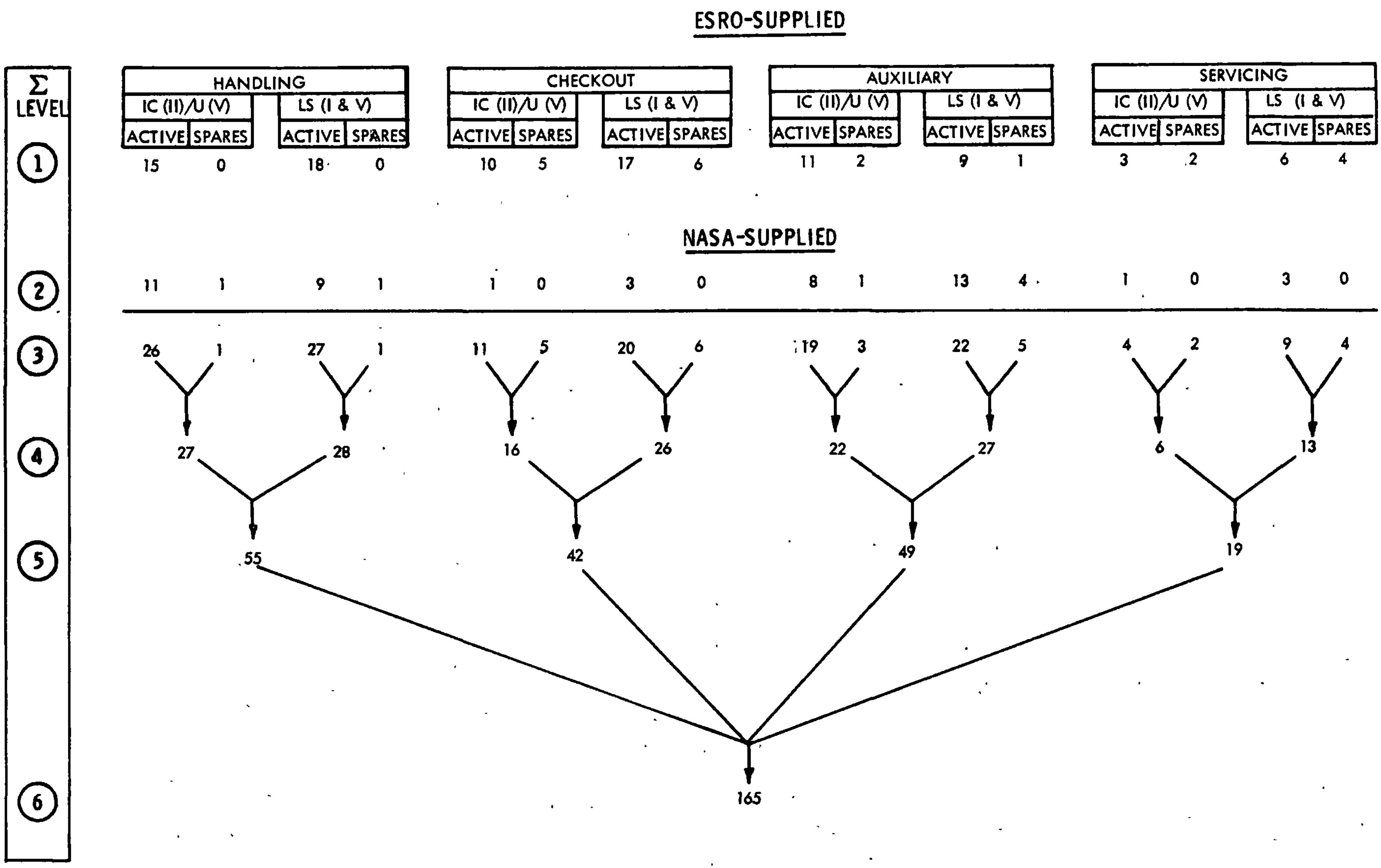

Figure 5.2-8. Spacelab Concepts II and IV GSE Requirements Summary

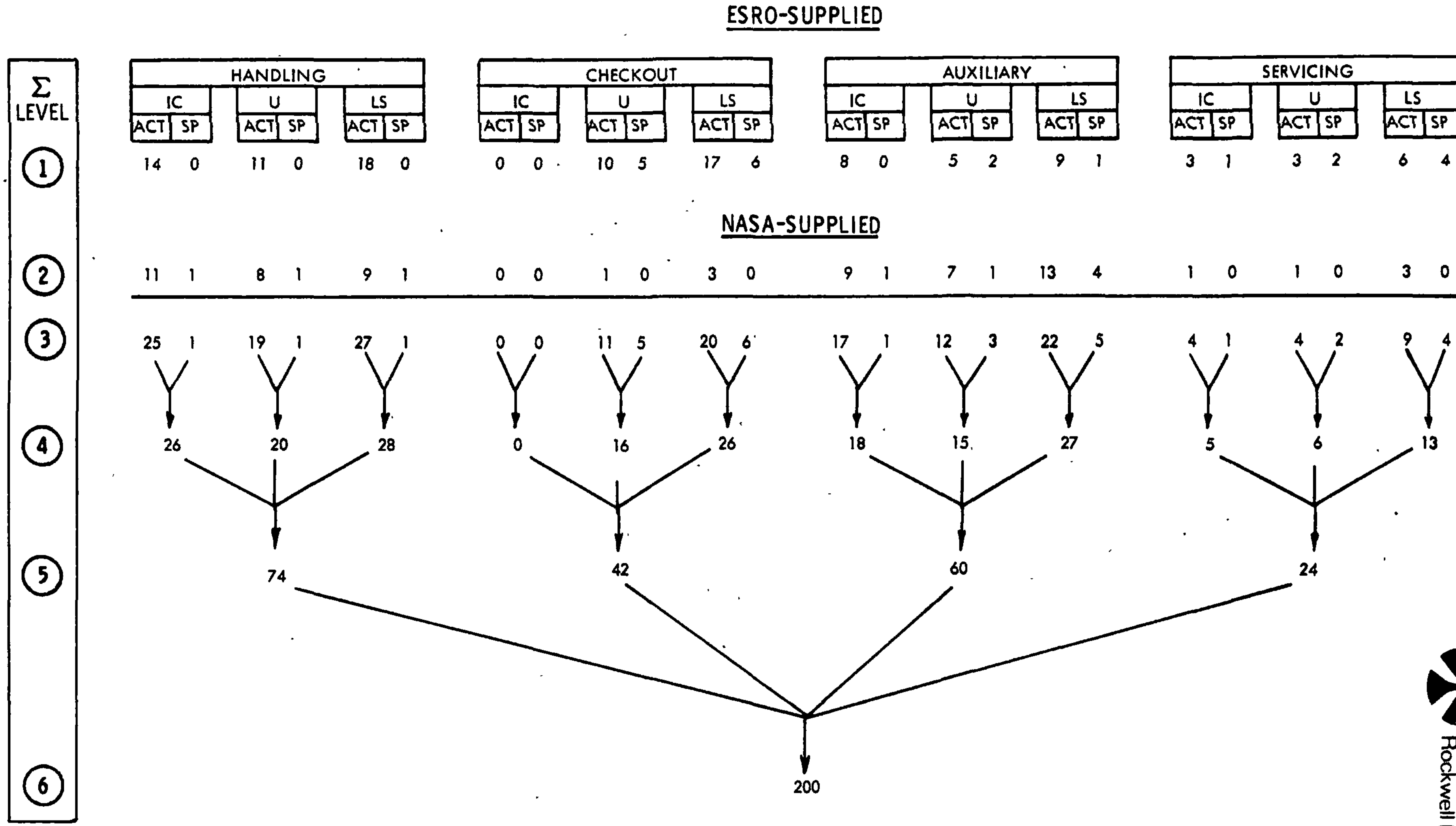

Figure 5.2-9. Spacelab Concept III GSE Requirements Summary

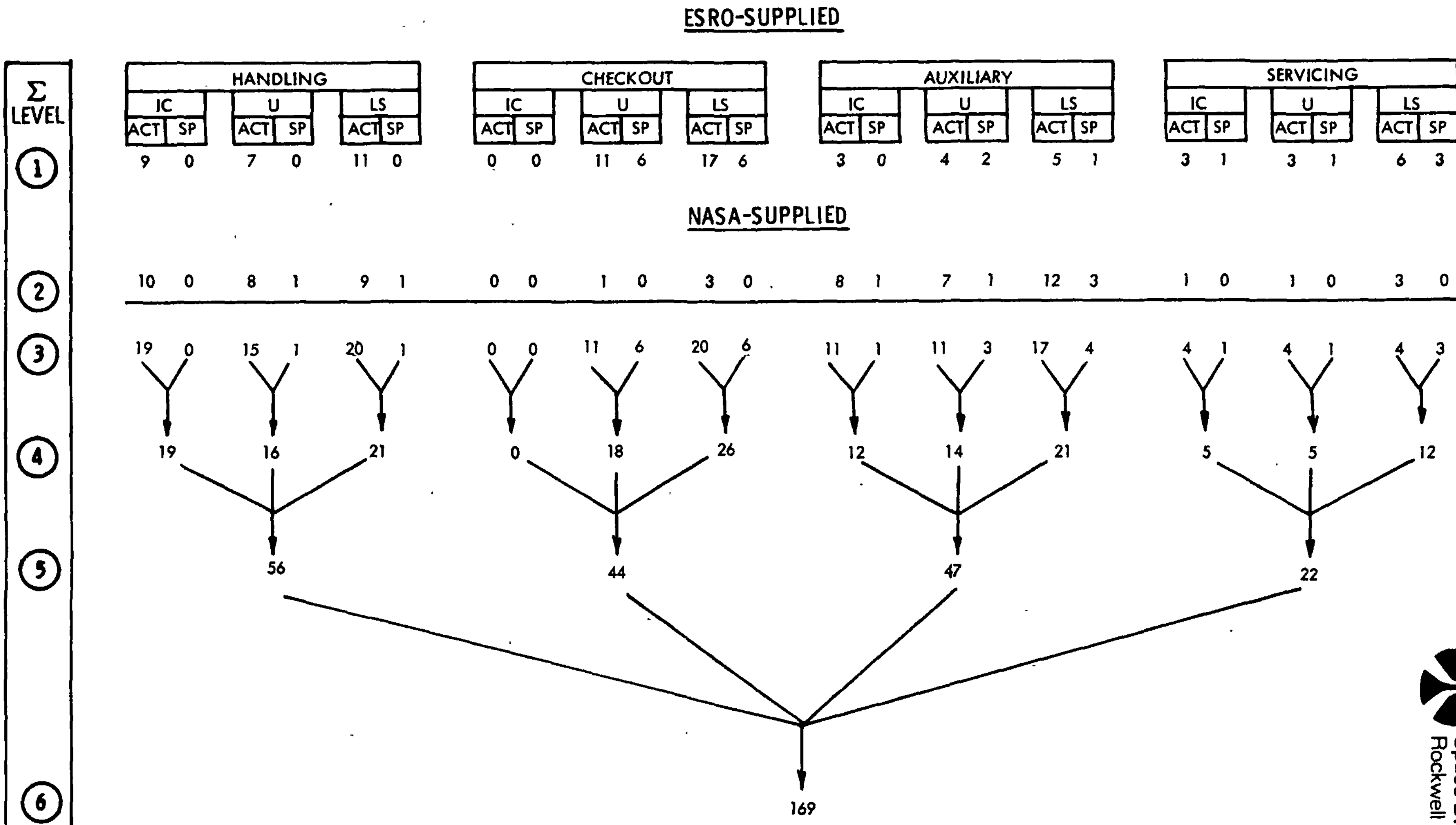

Figure 5.2-10. Pallet-Only Concept VI GSE Requirements Summary

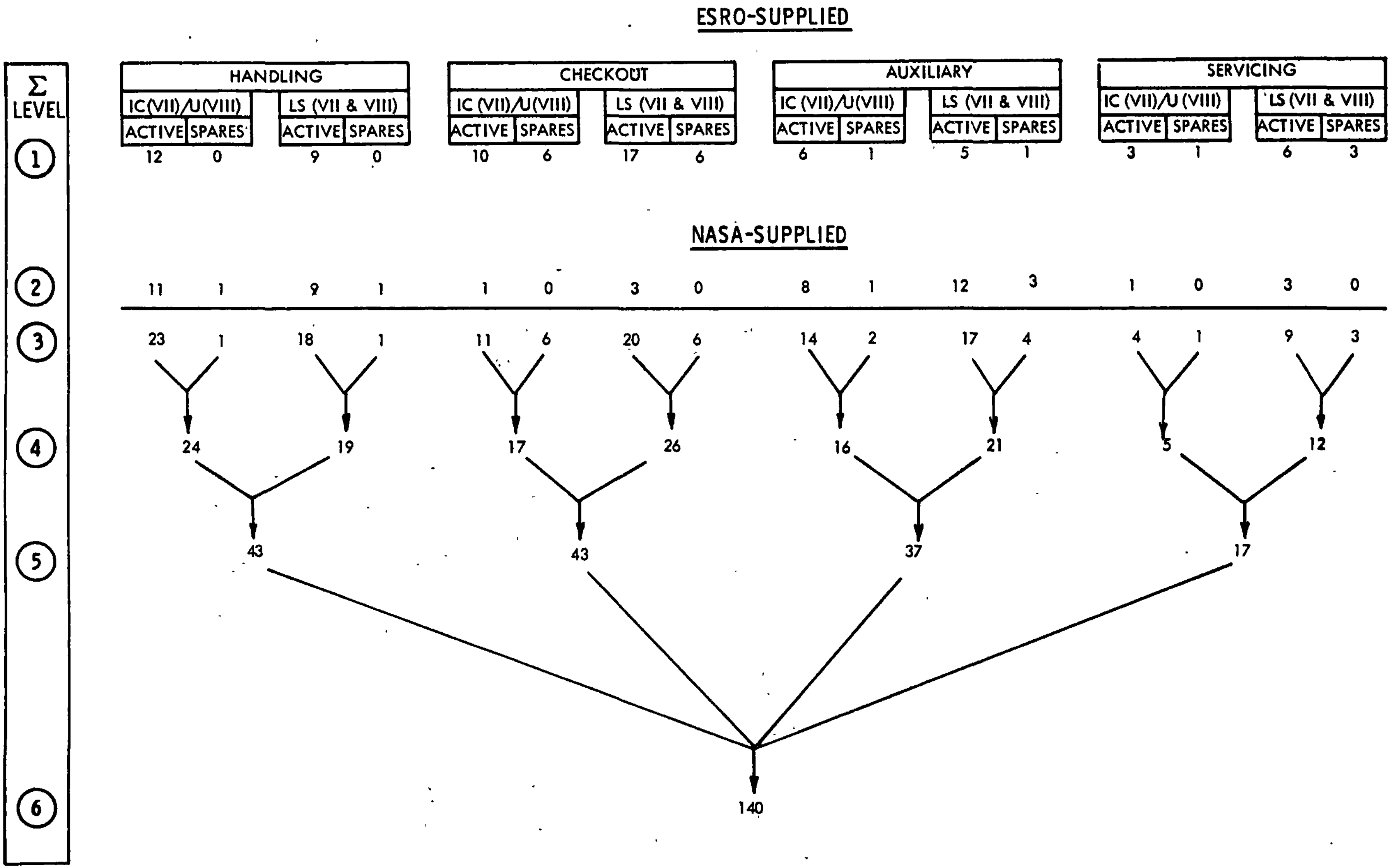

Figure 5.2-11. Pallet-Only Concepts VII and VIII GSE Requirements Summary

Table 5.2-8. GSE Requirements Summary

GSE \ CONCEPT	COMPLETE SPACELAB			PALLET-ONLY	
	I & V	II & IV	III	VI	VII & VIII
Handling	56	55	74	56	43
Checkout	35	42	42	44	43
Auxiliary	46	49	60	47	37
Servicing	20	19	24	22	17
Total (End Items)	157	165	200	169	140

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5.3 FACILITIES

Based upon the test and operations sequences developed in Volume II for each of the processing concepts, generic facility requirements were derived. Planned or potential accommodations at the various processing centers were then evaluated. Planned or existing facilities (with modifications) at MSFC and KSC completely encompass the generic requirements. Either new or major modifications of existing facilities are required at Langley.

FACILITIES REQUIREMENTS DEFINITION

A Spacelab test and operations scenario was constructed for each concept. Figure 5.3-1 illustrates the scenario for Concept I. From the scenario, a generic functional requirements matrix (Figure 5.3-2) was developed for each concept. Each set of requirements for each site was transformed into a conceptual building, taking into consideration the processing times and dwell times of equipment during each stage of installation, integration, and checkout. The conceptual designs of each facility for each concept are shown in Figures 5.3-3 through 5.3-9. Concept applicability, facility requirements and functional utilization are also indicated on the figures.

It should be noted that the currently defined ATL experiments do not require a 100K clean room environment during test and operations activities. However, a 100K clean room and associated airlocks were included in the facilities definitions because in a 10-year program such as the ATL it is highly probable that several experiments/payloads will require this environment.

In all cases where either the Spacelab modules or pallet are handled, a minimum hook height of 45 feet was specified. This height would permit the removal of a 15-foot-diameter payload from a shipping canister mounted on a transporter (15 feet) with appropriate spreader bars/handling cages/slings (10 feet) with a clearance of 5 feet.

Warehouse and Small Component Assembly Building (Figure 5.3-3)

This building consists of a bonded storage area which is air conditioned with controlled humidity and temperature, a small 100,000-class clean room with airlock for assembly of small experiment components, and a small component assembly area. The latter is not necessarily maintained at 100,000 cleanliness level, but is supplied by 100,000-class conditioned air. This facility is only required at the user center in those concepts were Level III/II/I integration is done off site.

Installation and Checkout Building (Figure 5.3-4)

The requirement for this building exists at the user's site when refurbishment of the rack/pallet assembly and SM/EM is done elsewhere. This building has electrical and mechanical laboratories that are environmentally controlled

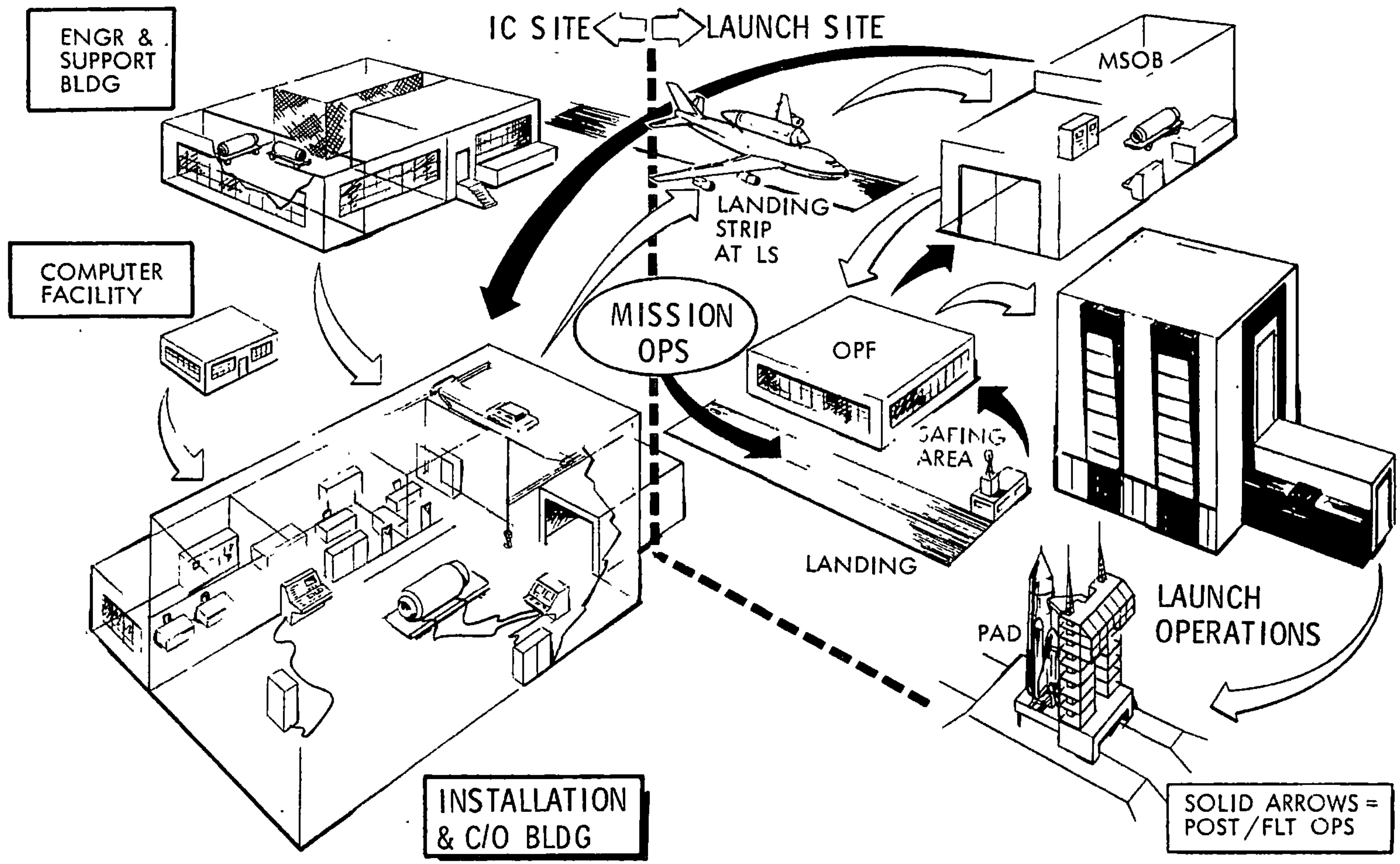


Figure 5.3-1. Concept I Spacelab Processing Flow

ENGINEERING & SUPPORT
1 BONDED STORAGE
2 RECEIVING/SHIPPING
3 EQUIP. STORAGE
4 ENGR OFFICES

COMPUTER FACILITY

INSTALLATION & C/O AREA
5 MECH BENCH TEST LAB
6 ELECT BENCH TEST LAB
7 OFFICES
8 EXPER INSTALL & C/O
9 EM/P REFURB
10 SM REFURB
11 EM/P PREPS & MATE
12 SM-EM/P MATE
13 SL INTEGRATION
14 PREP & SHIP

ORBITER INTEGRATION
15 ORB CARGO INTEG
16 SAFING AREA

V

IV/VIII — CENTER — FACILITY REQUIREMENTS

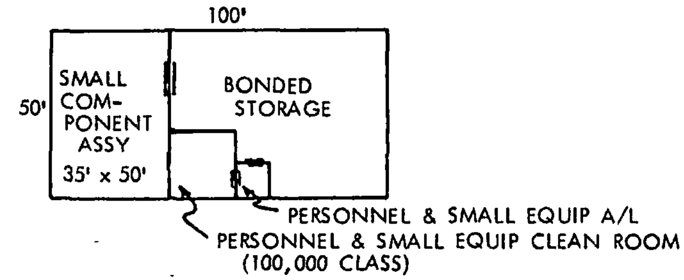
III/VI — CENTER — FACILITY REQUIREMENTS

II/VII — CENTER — FACILITY REQUIREMENTS

I

CENTER / BLDG	FACILITY REQUIREMENTS		
	USER	IC	LS
ENGR & SUPPORT	1,2, 3,4	1,2, 3,4	1,2,4
COMPUTER FACILITY	–	✓	✓
INSTL & CHECKOUT	–	5,6,7,8, 9,10,11, 12,13,14	5,6,7, 14
ORBITER INTEG	–	–	15,16

Figure 5.3-2. Facility Requirements Definition



CONCEPT UTILIZATION

I	USER	V	N/A
II	USER	VI	N/A
III	N/A	VII	USER
IV	N/A	VIII	N/A

FACILITY REQUIREMENT

	SPACE (FT^2)	ENVIRONMENT
(1) BONDED STORAGE	2750	AIR-CONDITIONED, T = 70 F, R/H = 50%
(2) SMALL COMPONENT ASSY AREA	1750	AIR-CONDITIONED, T = 70 F, R/H = 50%
(3) SMALL EQUIP CLEAN ROOM (100,000 CLASS)	400	T = 70 F, R/H = 50%, & 100,000 CLEAN LEVEL
(4) PERSONNEL & SMALL EQUIP A/L	100	T = 70 F, R/H = 50%, & 100,000 CLEAN LEVEL
TOTAL	5000	

FUNCTIONAL UTILIZATION

(1) BONDED STORAGE

(2) RECEIVING/INSPECTION AND SMALL COMPONENT ASSEMBLY (FOR CERTAIN EQUIPMENT ITEMS, THIS WOULD BE DONE IN THE CLEAN ROOM)

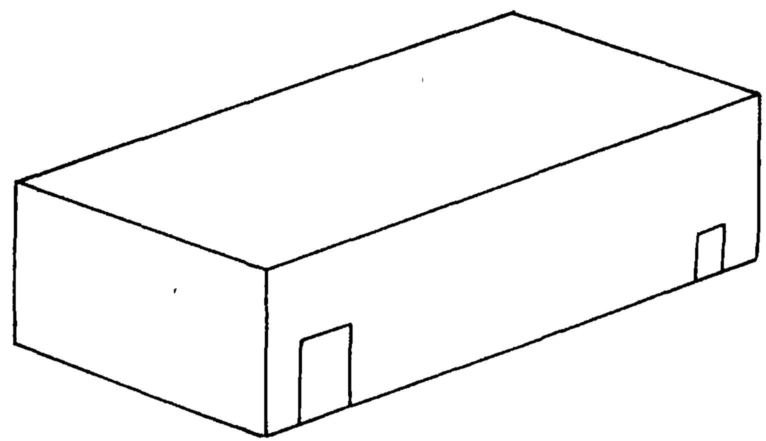
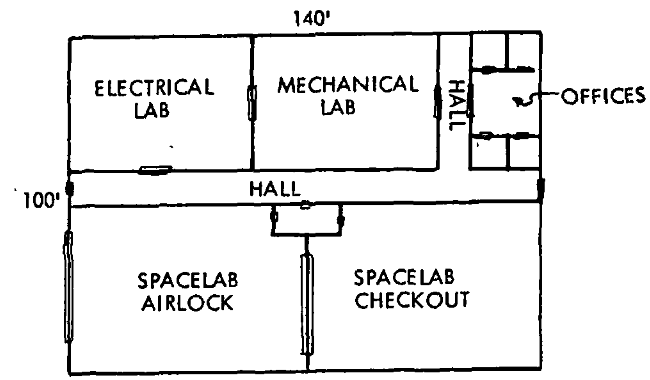


Figure 5.3-3. Warehouse and Small Component Assembly Building



CONCEPT UTILIZATION

I	N/A	VI	USER
II	N/A	VII	N/A
III	USER	VIII	N/A
IV	N/A		
V	N/A		

FACILITY REQUIREMENT

FACILITY REQUIREMENT	SPACE (FT^2)	ENVIRONMENT
(1) ELECTRICAL LAB	2200	AIR-CONDITIONED, T = 70 F, R/H = 50%
(2) MECHANICAL LAB	2200	AIR-CONDITIONED, T = 70 F, R/H = 50%
(3) OFFICES & CONNECTING HALLWAYS	2600	AIR-CONDITIONED, T = 70 F, R/H = 50%
(4) SPACELAB AIRLOCK	3400	T = 70 F, R/H = 50% & 100,000 CLEAN LEVEL
(5) SPACELAB CHECKOUT AREA	3400	T = 70 F, R/H = 50% & 100,000 CLEAN LEVEL
(6) SMALL EQUIP & PERSONNEL AIRLOCK	200	T = 70 F, R/H = 50% & 100,000 CLEAN LEVEL
TOTAL	14,000	

FUNCTIONAL UTILIZATION

(1) EXPERIMENT PREINSTALLATION
(2) EXPERIMENT INSTALLATION
(3) EXPERIMENT INTEGRATION
(4) RACKS/PALLET SHIPMENT PREPARATIONS
(5) RECEIVING/INSPECTION RACKS/PALLET (FROM IC)

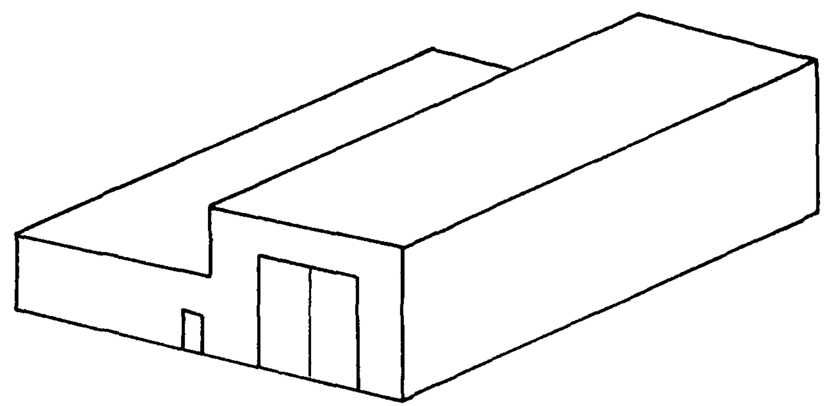


Figure 5.3-4. Installation and Checkout Building

but do not require 100,000-class cleanliness levels. A Spacelab airlock and checkout area are separately maintained at 100,000 cleanliness levels. It is in this latter area that experiment installation and integration are accomplished at the user's site. Office space and a personnel airlock to the checkout area is also a requirement for this building.

Warehouse (Figure 5.3-5)

A general storage facility or warehouse is necessary for Spacelab processing and is required at Level III integration sites. The warehouse is comprised of a general storage area that is environmentally controlled (300,000 class) but not to stringent cleanliness levels. A bonded storage section is also required with similar characteristics. A small equipment clean room (100,000 class) will be necessary for disassembly/assembly of small parts that undergo receiving and inspection. For the clean room, a personnel and small equipment airlock is required.

Refurbishment and Checkout Building (Figure 5.3-6)

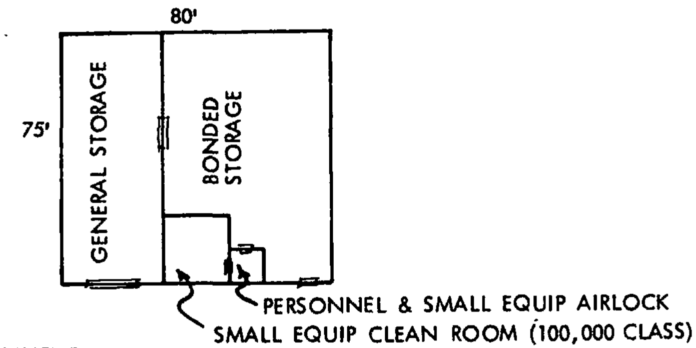
The requirement for this facility is at the integration center. This building is similar to the installation and checkout building, but deletes the requirement for the 100,000 cleanliness level (and airlock). The primary purpose for this building is to refurbish the rack/pallet assembly and, since this equipment has just completed its mission, there are no stringent requirements for cleanliness-level control although the building will still require temperature and humidity control.

Installation, Checkout and Refurbishment Building (Figure 5.3-7)

The requirement for this building is necessary in all concepts (except III/VI). This structure combines features of both buildings illustrated in Figures 5.3-4 and 5.3-6; and accommodates installation, checkout and refurbishment operations. The single airlock provided allows the Spacelab, or its elements, to be moved directly from the refurbishment area to the experiment installation and checkout area. Spacelab integration can also be accomplished in this facility.

Spacelab Assembly, Checkout and Refurbishment Area (Figure 5.3-8)

This area is a modification to the MSOB to support the Spacelab processing at the launch site. The data presented in Figure 5.3-8 were extracted from NASA (KSC) Report No. TR-1298, dated August 1, 1974. The data were further modified to accommodate the Spacelab configurations to be processed in that facility for the various concepts. A ground rule for Spacelab processing was that no test/operations would be permitted outside an enclosure or room not controlled to cleanliness level 100,000. Therefore, the MSOB modification reflects an airlock and closeout bulkhead approximately at Column 9 of the MSOB, or at the point where the high bay begins at the east end of the building. This entire high bay area is shown as controlled to cleanliness level 100,000. The required cleanliness level could be achieved by movable soft enclosures that would encompass the immediate work area to facilitate localized cleanliness control.



CONCEPT UTILIZATION

I	IC	V	USER
II	IC	VI	USER
III	USER	VII	IC
IV	USER	VIII	USER

FACILITY REQUIREMENT

FACILITY REQUIREMENT	SPACE (FT^2)	ENVIRONMENT
(1) GENERAL STORAGE	2250	AIR-CONDITIONED, T = 70 F, R/H = 50%
(2) BONDED STORAGE	3250	AIR-CONDITIONED, T = 70 F, R/H = 50%
(3) SMALL EQUIP CLEAN ROOM (100,000 CLASS)	400	T = 70 F, R/H = 50% & 100,000 CLEAN LEVEL
(4) PERSONNEL & SMALL EQUIP AIRLOCK	100	T = 70 F, R/H = 50% & 100,000 CLEAN LEVEL
TOTAL	6000	

FUNCTIONAL UTILIZATION

(1) STORAGE FOR GENERAL SPACELAB ELEMENTS
(2) SPARES STORAGE
(3) BONDED STORAGE
(4) RECEIVING/INSPECTION OF SMALL COMPONENTS
(5) BIN STORAGE OF MISCELLANEOUS ITEMS OF LOOSE HARDWARE--NUTS, BOLTS, SCREWS, WASHERS, ETC.

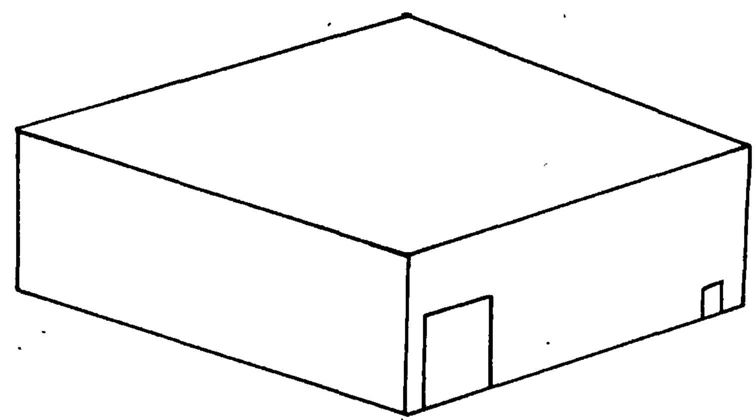
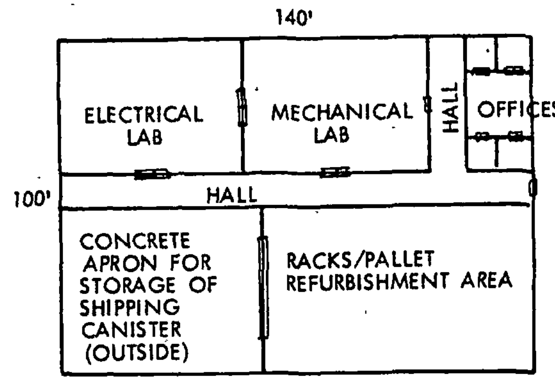


Figure 5.3-5. Warehouse



CONCEPT UTILIZATION

I	N/A	V	N/A
II	N/A	VI	IC
III	IC	VII	N/A
IV	N/A	VIII	N/A

FACILITY REQUIREMENT

	SPACE (FT^2)	ENVIRONMENT
(1) ELECTRICAL LAB	2200	AIR-CONDITIONED, T = 70 F, R/H = 50%
(2) MECHANICAL LAB	2200	AIR-CONDITIONED, T = 70 F, R/H = 50%
(3) OFFICE & CONNECTING HALLWAYS	2600	AIR-CONDITIONED, T = 70 F, R/H = 50%
(4) RACKS/PALLET REFURB & CHECKOUT AREA	4000	AIR-CONDITIONED, T = 70 F, R/H = 50%
TOTAL	11,000 *	

*3000 FT^2 CONCRETE APRON NOT INCLUDED

FUNCTIONAL UTILIZATION

(1) RECEIVING/INSPECTION OF RACKS/PALLET

(2) REFURBISH RACKS/PALLET

(3) POST-REFURBISH RACKS/PALLET SHIPMENT PREPARATIONS

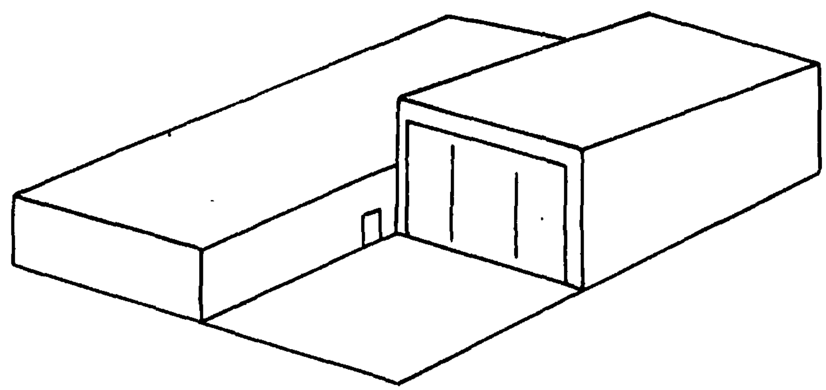
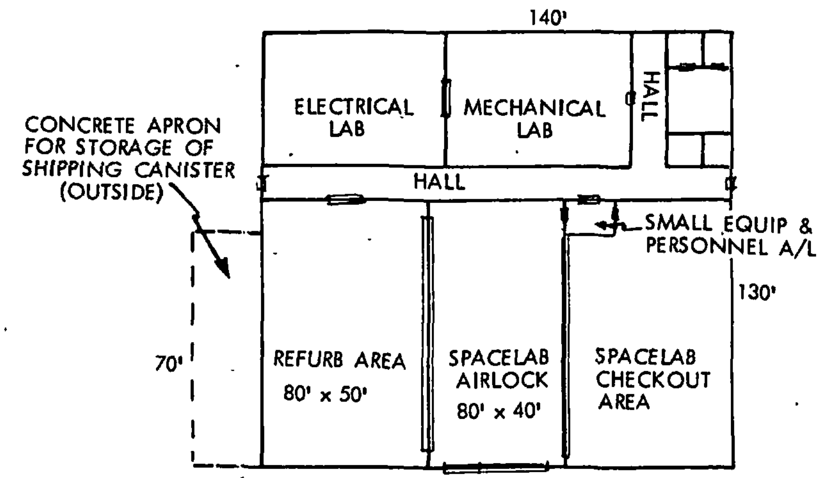


Figure 5.3-6. Refurbishment and Checkout Building

CONCEPT UTILIZATION

I	IC
II	IC
III	NOT APPLICABLE
IV	USER
V	USER
VI	NOT APPLICABLE
VII	IC
VIII	USER



FACILITY REQUIREMENT

	SPACE (FT^2)	
(1) ELECTRICAL LAB	2200	AIR-CONDITIONED, T = 70 F, R/H 50%
(2) MECHANICAL LAB	2200	AIR-CONDITIONED, T = 70 F, R/H 50%
(3) OFFICES & CONNECTING HALLWAYS	2600	AIR-CONDITIONED, T = 70 F, R/H 50%
(4) REFURBISHMENT AREA	4000	AIR-CONDITIONED, T = 70 F, R/H 50%
(5) SPACELAB AIRLOCK	3200	T = 70 F, R/H 50% & 100,000 CLEAN LEVEL
(6) SPACELAB CHECKOUT AREA	3850	T = 70 F, R/H 50% & 100,000 CLEAN LEVEL
(7) SMALL EQUIP & PERSONNEL AIRLOCK	150	T = 70 F, R/H 50% & 100,000 CLEAN LEVEL
TOTAL	18,200*	

*1750 FT^2 CONCRETE APRON NOT INCLUDED

FUNCTIONAL UTILIZATION

(1) EXPERIMENT PRE-INTEGRATION
(2) EXPERIMENT INSTALLATION
(3) EXPERIMENT INTEGRATION
(4) MATE RACKS/PALLET-EM/SM SHELLS
(5) SPACELAB INTEGRATION
(6) SPACELAB SHIPMENT PREPARATIONS
(7) DEMATE EM/SM SHELLS
(8) REFURBISH RACKS/PALLET
(9) REFURBISH SUPPORT SYSTEMS-
EM/SM SHELLS
(10) R/I & POST-FLIGHT INSPECTION

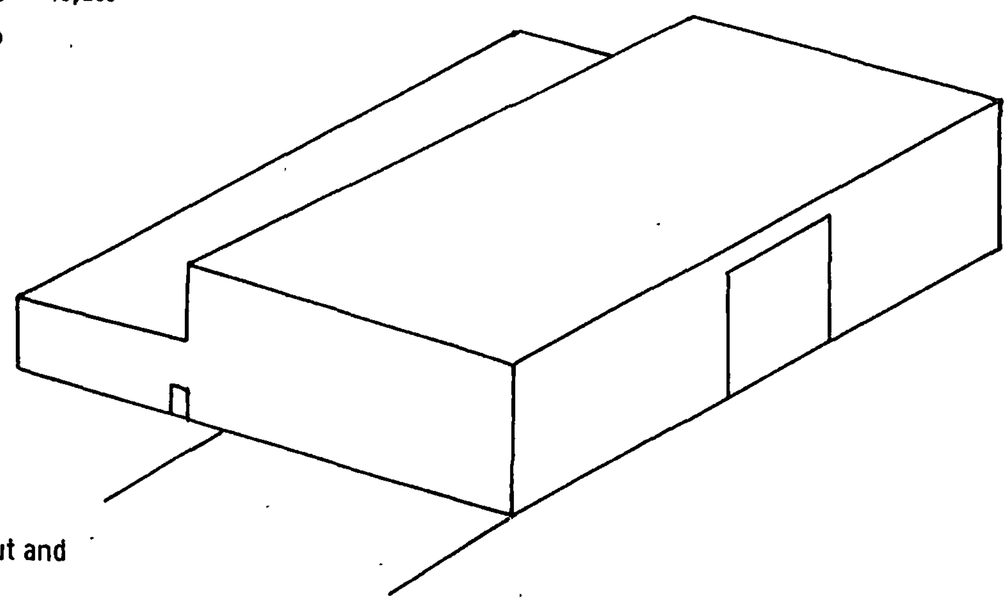


Figure 5.3-7. Installation, Checkout and Refurbishment Building

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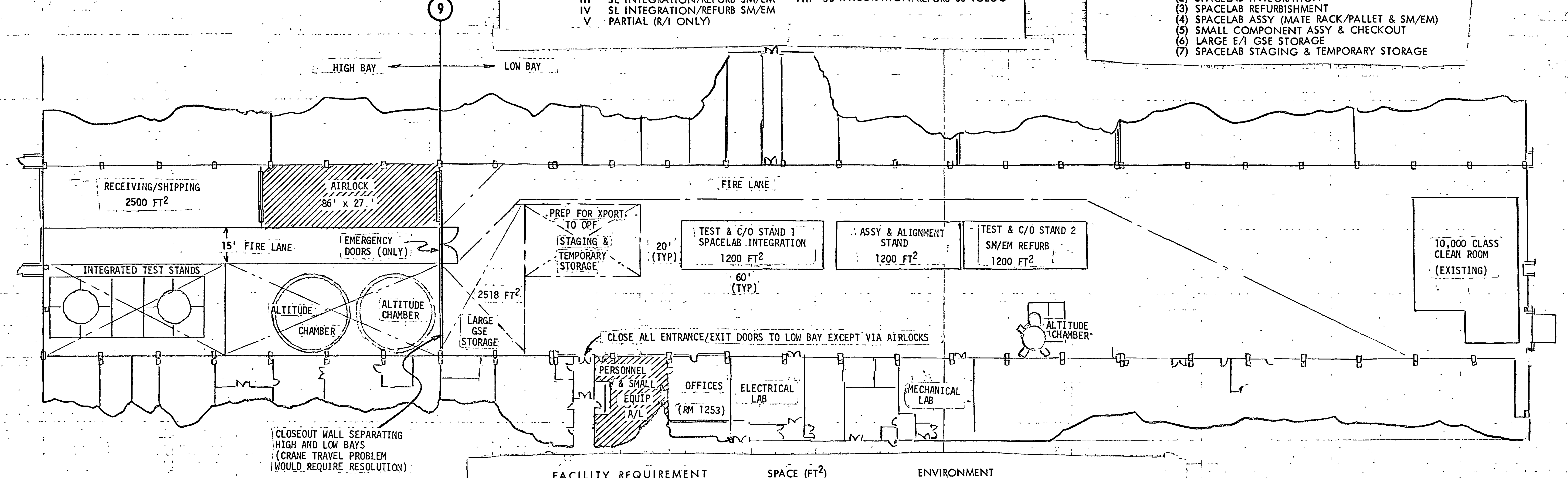
CONCEPT UTILIZATION

I	PARTIAL (R/I ONLY)	VI	SL INTEGRATION/REFURB SS IGLOO
II	SL INTEGRATION/REFURB SM/EM	VII	SL INTEGRATION/REFURB SS IGLOO
III	SL INTEGRATION/REFURB SM/EM	VIII	SL INTEGRATION/REFURB SS IGLOO
IV	SL INTEGRATION/REFURB SM/EM		
V	PARTIAL (R/I ONLY)		

FUNCTIONAL UTILIZATION

(1) SPACELAB RECIVING/INSPECTION
(2) SPACELAB INTEGRATION
(3) SPACELAB REFURBISHMENT
(4) SPACELAB ASSY (MATE RACK/PALLET & SM/EM)
(5) SMALL COMPONENT ASSY & CHECKOUT
(6) LARGE E/I GSE STORAGE
(7) SPACELAB STAGING & TEMPORARY STORAGE



FACILITY REQUIREMENT	SPACE (FT^2)	ENVIRONMENT
(1) ELECTRICAL LAB	1000	AIR-CONDITIONED, T = 70 F, R/H = 50%
(2) MECHANICAL LAB	1000	AIR-CONDITIONED, T = 70 F, R/H = 50%
(3) OFFICE SPACE	800	AIR-CONDITIONED, T = 70 F, R/H = 50%
(4) SPACELAB AIRLOCK	2160	T = 70 F, R/H 50%, 100K CLEAN LEVEL
(5) SPACELAB C/O REFURB AREA	3600	T = 70 F, R/H 50%, 100K CLEAN LEVEL
(6) STAGING & TEMPORARY STORAGE	1250	T = 70 F, R/H 50%, 100K CLEAN LEVEL
(7) LARGE GSE STORAGE	2518	T = 70 F, R/H 50%, 100K CLEAN LEVEL
(8) RECEIVING/SHIPPING	2500	T = 70 F, R/H 50%, 100K CLEAN LEVEL
(9) PERSONNEL & SMALL EQUIP A/L	1000	T = 70 F, R/H 50%, 100K CLEAN LEVEL
TOTAL	15,828	

Figure 5.3-8. Spacelab Assembly, Checkout and Refurbishment Area

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Spacelab/Orbiter Cargo Integration Preparation Area (Figure 5.3-9)

An area is required to offload the Spacelab at the OPF, to conduct pre-installation checks, and to perform some minor servicing operations. Similar areas are shown in the preliminary design of each of the bays of the proposed OPF at KSC.

Operations Control Center (Figure 5.3-10)

An operations control center is required (for all concepts) at the user's site to monitor and support real-time mission activities. The facility has mission monitor consoles, office space, a world map that displays real-time ground traces of the Spacelab flight path for ground truth site coordination, leased telephone lines, recorders, copying (repro) machines, telecopier, and TWX services. A DOMSAT ground terminal is also included. The facility is environmentally controlled to 70 F and 50-percent relative humidity, or to a comfort index level for personnel utilizing the facility. Mini-processors are assumed to operate the world map and the data display consoles.

Operations control centers at the integration center, launch site, and mission control are assumed to be basic facilities that will be developed to support all payloads and Shuttle operations.

Personnel Office Space

Provisions are also required for engineering office space for both the resident staff and off-site or transient support personnel. Office space allocations for mission unique personnel (developed in Section 3.0 of this volume) of 100 square feet per man were made.

Facility Requirements Summary

Some combination of the above described facilities is required for each concept. A summary listing of the facility area requirements per concept and site is provided in Table 5.3-1. The variations are not considered to be significant.

FACILITY REQUIREMENTS ACCOMMODATIONS

The facility requirements for processing the Spacelab for the various concepts were generically determined. It should be recognized that the user (Langley) is concerned with a single payload, viz., the ATL Spacelab. Conversely, the integration center (MSFC) and launch site (KSC), in the context of this discussion are required to support various multi-discipline payloads, possibly up to 24 payloads per year. Thus, it is evident that the latter commitment imposes much greater facility requirements at the integration center and launch site for payload processing then at Langley, regardless of the ATL Spacelab processing concepts. The accommodations at the various centers to the generic facility requirements are discussed below.

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CONCEPT UTILIZATION

I	ORBITER CARGO INTEGRATION	VI	ORBITER CARGO INTEGRATION
II	ORBITER CARGO INTEGRATION	VII	ORBITER CARGO INTEGRATION
III	ORBITER CARGO INTEGRATION	VIII	ORBITER CARGO INTEGRATION
IV	ORBITER CARGO INTEGRATION		
V	ORBITER CARGO INTEGRATION		

FACILITY REQUIREMENT

SPACELAB ORBITER CARGO INTEGRATION PREPARATION AREA

5600 FT^2

FUNCTIONAL UTILIZATION

(1) SPACELAB OFFLOAD
(2) SL LOW-PRESS GAS SERVICING
(3) SL/ORBITER FIT CHECK (IF REQ'D)
(4) SL/ORBITER PRE-INSTALLATION CHECKS

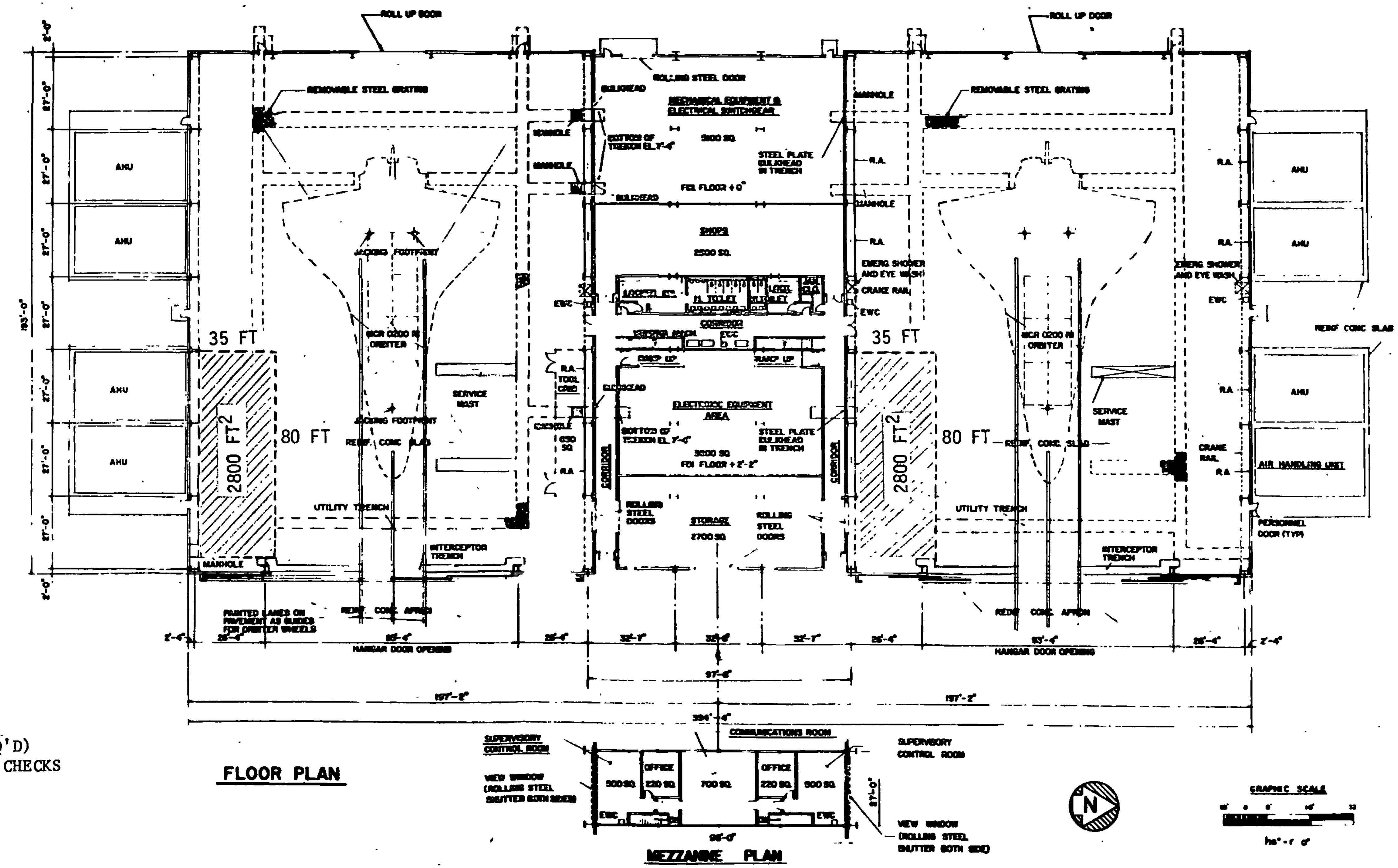

Figure 5.3-9. Orbiter Processing Facility (OPF) - Floor Plan

CONCEPT UTILIZATION

(ALL)

FACILITY REQUIREMENT

(1) MISSION MONITOR CONSOLES
(2) OFFICE SPACE
(3) ORBITAL GROUND PATH TRACE (WORLD MAP)
(4) WALL SPEAKERS
(5) MULTIPLE TELEPHONES
(6) HEAD SETS
(7) TAPE RECORDERS
(8) LEASED TELEPHONE LINES
(9) REPRO - TELECOPIER - TWX

FUNCTIONAL UTILIZATION

(1) MONITOR AND SUPPORT MISSION ACTIVITIES
(2) COORDINATE GROUND TRUTH TARGET ACTIVITY
(3) CONFERENCE ROOM

AREA

40 FT X 60 FT = 2400 FT^2

ENVIRONMENT

AIR-CONDITIONED, T = 70 F, R/H = 50%

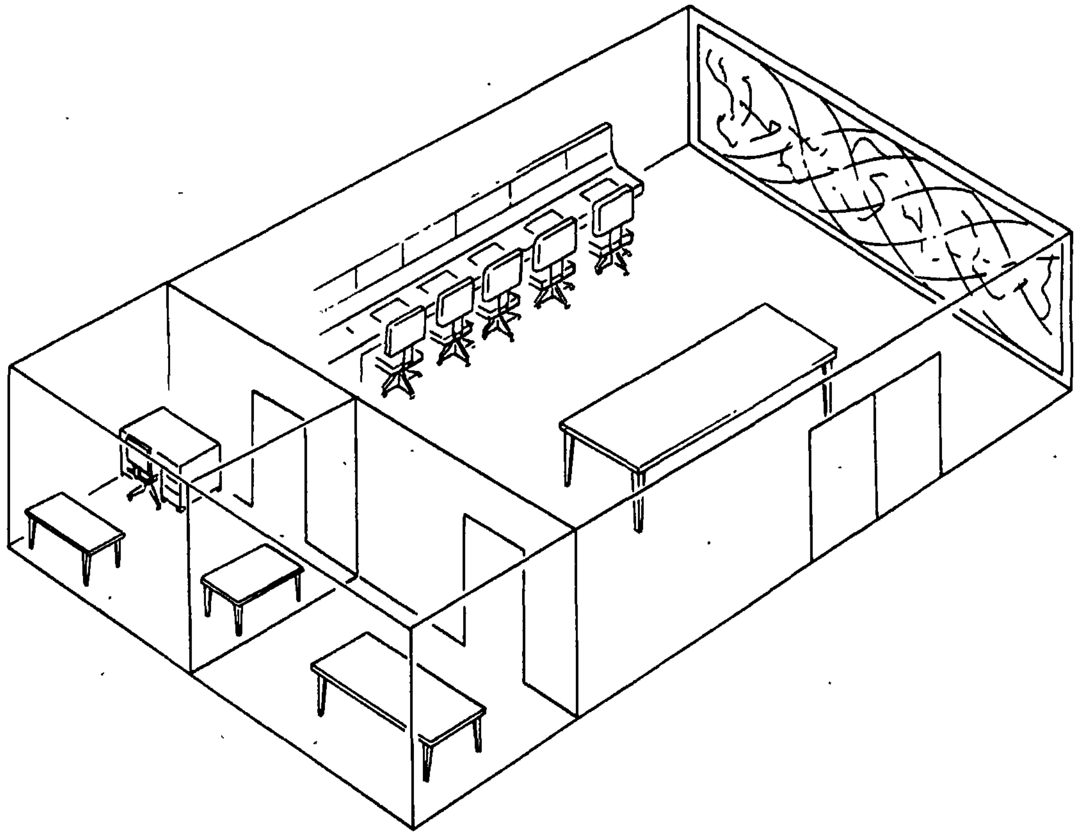

Figure 5.3-10. Operations Control Center

Table 5.3-1. Summary of Facility Requirements

FACILITY	SPACELAB FACILITY AREA REQUIREMENTS (FT^2)																							
	CONCEPT I			CONCEPT II			CONCEPT III			CONCEPT IV			CONCEPT V			CONCEPT VI			CONCEPT VII			CONCEPT VIII		
	U	IC	LS	U	IC	LS	U	IC	LS	U	IC	LS	U	IC	LS	U	IC	LS	U	IC	LS	U	IC	LS
WAREHOUSE & SMALL COMPONENT ASSEMBLY BUILDING	5,000			5,000															5,000					
INSTALLATION & CHECKOUT BLDG.[5]							14,000									14,000								
WAREHOUSE		6,000			6,000		6,000			6,000			6,000			6,000				6,000		6,000		
REFURBISHMENT AND CHECKOUT BUILDING [1,5]								11,000									11,000							
INSTALLATION, CHECKOUT AND REFURBISHMENT BUILDING [2,5]		18,200			18,200					18,200			18,200							18,200		18,200		
CARGO PROCESSING [3,5]			7,000			15,828			15,828			15,828			7,000			15,828			15,828			15,828
ORBITER PROCESSING FACILITY (OPF) [4,5]			5,600			5,600			5,600			5,600			5,600			5,600			5,600			5,600
PERSONNEL OFFICE SPACE	2,600	6,000	1,000	2,700	5,500	1,600	6,500	1,800	1,600	7,800		1,600	8,300		1,000	6,500	1,800	1,600	2,700	5,500	1,600	7,800		1,600
OPERATIONS CONTROL CENTER	2,400			2,400			2,400			2,400			2,400			2,400			2,400			2,400		
SITE TOTALS	10,000	30,200	13,600	10,100	29,700	23,028	28,900	12,800	23,028	34,400	-	23,028	34,900	-	13,600	28,900	12,800	23,028	10,100	29,700	23,028	34,400	-	23,028
CONCEPT TOTALS	53,800			62,828			64,728			57,428			48,500			64,728			62,828			57,428		

1. 3000 FT^2 CONCRETE APRON NOT INCLUDED.
2. 1750 FT^2 CONCRETE APRON NOT INCLUDED.
3. EXISTING KSC FACILITY.
4. PLANNED KSC SHUTTLE FACILITY
5. MINIMUM HOOK HEIGHT OF 45 FEET

User (Langley Research Center)

Facilities personnel at Langley reviewed the generic facility requirements as they were developed. Their evaluation indicated that, with major modifications, Building 1293A (at Langley) could be utilized for ATL Spacelab processing. The functional utilization and sequence of operations indicated in Figure 5.3-11 will support any and all test/operations specified for those concepts in which the user (Langley) performs Level III or Level II integration.

In Concepts I and II only, bonded storage, receiving and shipping, and engineering office space are required at the user site (Langley) to support the processing of the ATL Spacelab. Existing facilities are adequate for these functions.

At the present time there is no existing or planned facility at Langley that will provide the functions of the operations control center that is required for all concepts. A new building is not required. Space in existing buildings could be utilized. The primary modification would be the installation of a DOMSAT ground terminal.

Because the required modifications to Building 1293A are so extensive and the availability of this building to support the ATL Spacelab program could not be established, Langley personnel also developed a conceptual design of a new integration and checkout facility (Figure 5.3-12). Gross estimates indicate that the cost of the new facility and the modification to Building 1293A are about the same. For purposes of this study, modification of Building 1293A was adopted as the baseline.

Integration Center (MSFC)

Current planning at MSFC is for the conversion of Building 4755 to a Spacelab processing facility. This one building has in excess of 60,000 square feet of floor space. Table 5.3-2 presents a preliminary space allocation for the various Spacelab processing functions. Figure 5.3-13 shows a rough layout of the various work areas. Based upon a two-shift/five-day work week it is anticipated that up to 20 Spacelabs can be processed through this facility each year.

Existing bonded storage, shipping/receiving, office space, and operations control center (S-II and Skylab) facilities are applicable for Spacelab activities. It is assumed that the operations control center will be expanded/updated and include a DOMSAT ground terminal to support all types of payloads in the 1980's that are under the cognizance of MSFC.

Launch Site (KSC)

The planned facilities at KSC will accommodate all the generic Spacelab processing requirements defined in this study. The OPF (Figure 5.3-6) described in an earlier part of this section of the report is being designed to accommodate a broad range of orbiter payloads and are not unique facilities for the

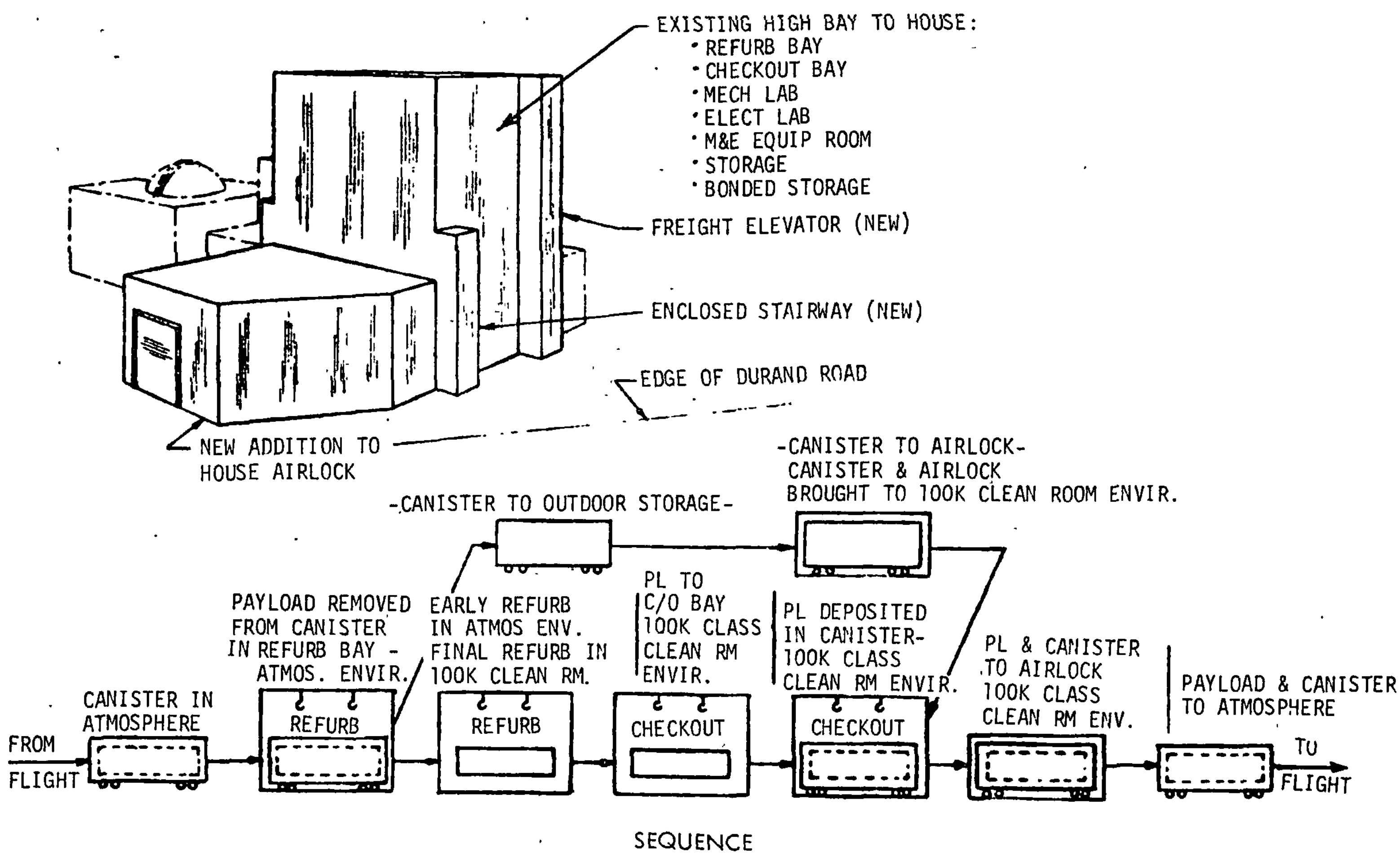

Figure 5.3-11. Modifications and Additions to Bldg. 1293A to House Installation and Checkout and Storage Facility

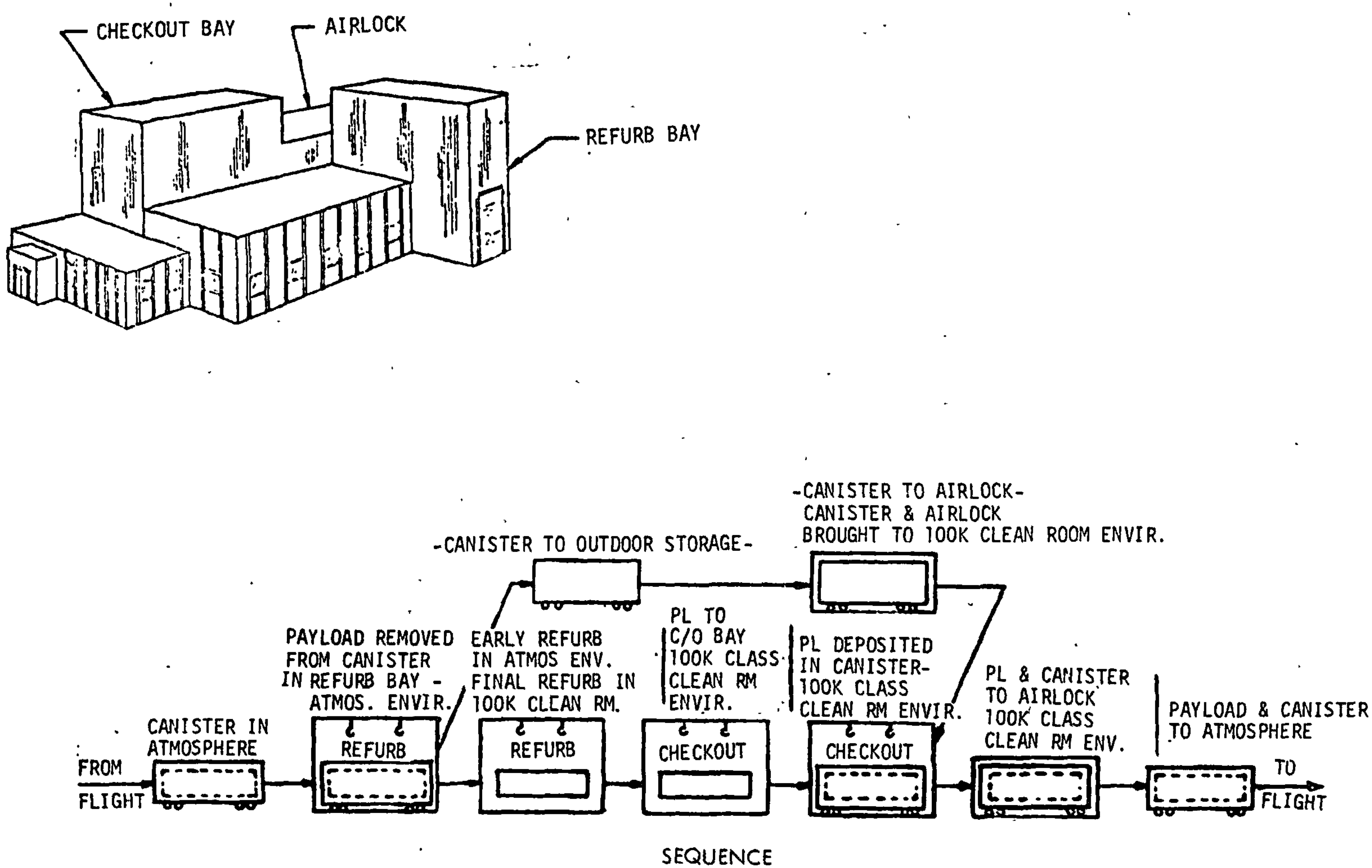

Figure 5.3-12. New Installation and Checkout Building at Langley

Table 5.3-2. MSFC Spacelab Processing Facility

AREA		FT^2
EXPERIMENT CHECKOUT AND SERVICING		
100 x 50 = 5000		5,000
SPACELAB CHECKOUT		
70 x 130 = 9100		9,100
ASSEMBLY		
40 x 130 (2) = 10,400		10,400
INSPECTION, DISASSEMBLY AND REFURBISHMENT		
Inspection and Disassembly (Spacelab)		
60 x 80 = 4800		
Disassembly and Refurbishment (Assemblies)		
50 x 60 = 3000 50 x 100 = 5000	8000	12,800
CLEANING		
62 x 36 = 2200		2,200
RECEIVING, INSPECTION, AND PACKAGING		
62 x 50 = 3100		3,100
STORES AND SUPPLIES		
25 x 40 = 1000		1,000
EXPERIMENT STORAGE		
25 x 20 = 500		
OFFICE AREA		
First Floor = 600		
Second Floor = 2,800		
Third Floor = 2,800	16,200	16,200
Fourth Floor = 10,000		
	TOTAL AREA	60,300
PROPOSED ADDITIONS		
Computer and Integrated Checkout Equipment (30 x 81)		2,400
Experiment Facilities (25 x 81)		2,000
	PROPOSED TOTAL AREA	64,700

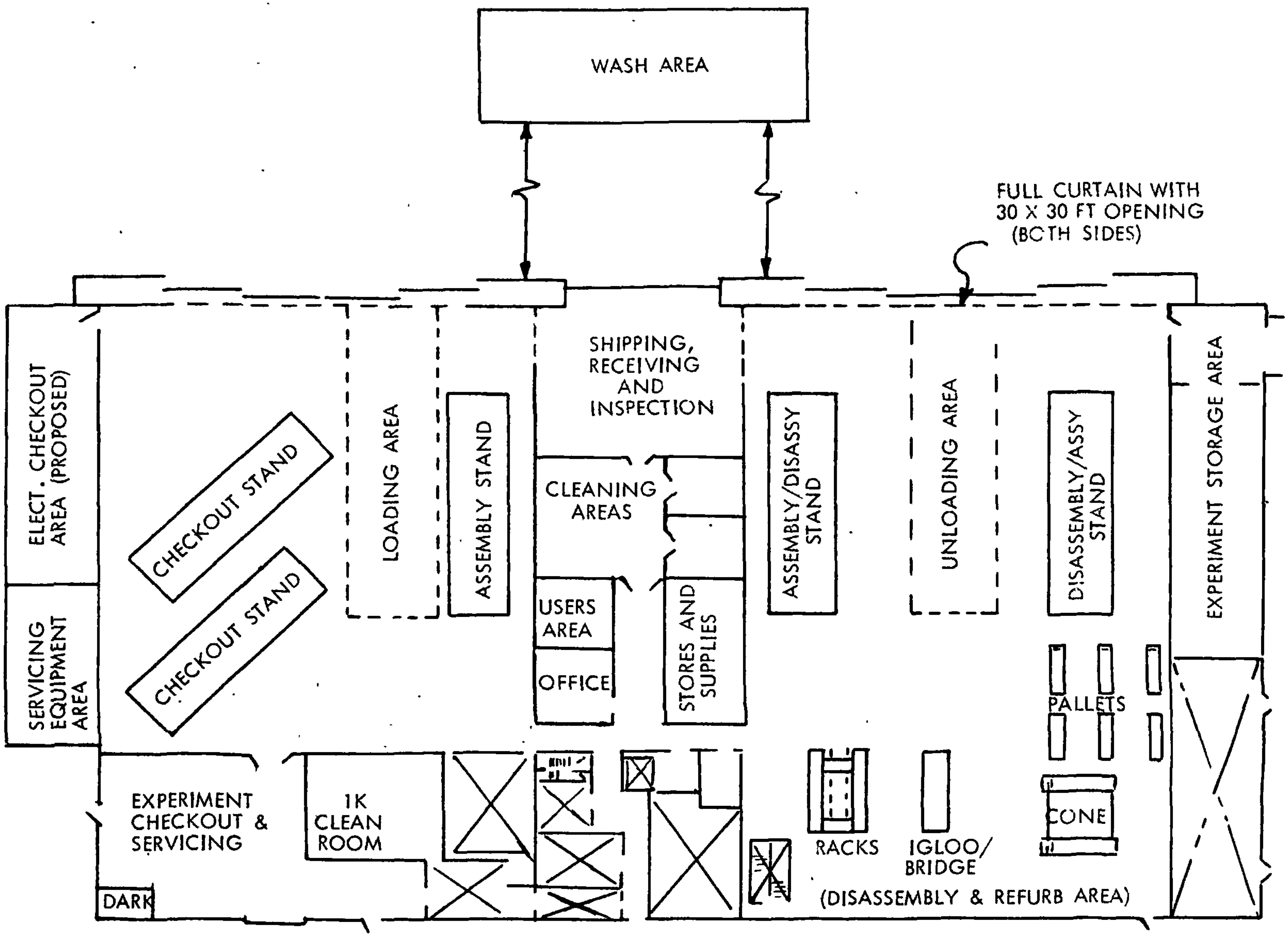

Figure 5.3-13. Spacelab Processing Facility (MSFC)

ATL Spacelab. The required modifications to the MSOB (Figure 5.3-7) are considered to be relatively minor. Bonded storage, receiving/shipping, and office space are compatible with Spacelab processing requirements.

Accommodations Summary

Either existing or planned general-purpose facilities at the integration center (MSFC) and the launch site (KSC) will be compatible with the integration and checkout requirements of the ATL Spacelab regardless of the Spacelab configuration or processing concept. Major modifications to an existing facility (Building 1293A) is required at the user site (Langley) in six of the concepts for Level II and/or III integration. In all concepts, an operations control center must be developed at the user site.

6.0 PROGRAMMATIC COSTING

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In this section, cost estimates for all the resource requirements defined in previous sections are presented. The data are grouped into three cost categories: mission-unique, sustaining, and non-recurring. Mission-unique costs, including personnel and support services, vary from $1.7 million to $1.8 million per flight across the candidate concepts. Yearly sustaining costs including personnel, maintenance of Spacelab processing equipment and facilities, and institutional base support vary from $675 thousand to $744 thousand across the concepts. Non-recurring costs for GSE, facilities, and personnel vary from $21 million to $29 million across the concepts.

Three test activities that have been included in previous space programs were deleted from the test and operations sequences developed in this study. The deletion of these three tests (thermal-vacuum, vibration-acoustic, and repeat functional testing) from the hardware integration activities was based upon the operational nature of the Shuttle/Spacelab program, the return of experimental equipment, and the opportunity for reflight. A cost-risk analysis of these deletions is presented in this section. The data indicate that with reasonable probabilities of failure, it is more cost-effective to refly an experiment because of a failure rather than subject an entire payload to the tests in question.

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6.1 MISSION-UNIQUE COST ESTIMATES

Table 6.1-1 summarizes the mission-unique cost estimates for all the processing concepts. Although the costs are for a single mission, the estimates reflect the integration and checkout approach derived in this study of 2 flights per year, 3 missions in development concurrently, and an 18-month duration for the entire integration cycle. The similarity between three of the complete Spacelab processing concepts and the three pallet-only payload processing concepts permitted the combining of the appropriate sets. All costs are in 1974 dollars.

Material costs include cables, connectors, brackets, mockups, and special GSE required for each mission. Cost estimating relationships based upon previous Rockwell programs were utilized in deriving the estimates.

Travel estimates include airfare and per-diem expenses, but not the salaries of personnel on trip status.

Auto computation costs reflect the required run time on a large-scale computer such as the IBM 370 for the development of checkout and flight software, and computer-aided analyses associated with various support function tasks.

Documentation costs are solely for the publication and distribution effort. Engineering time to produce the technical contents of the documents is included in personnel estimates.

Commercial air freight rates were used to estimate the shipping costs of experiment equipment between sites (Concepts I and II/VII only). As no estimates for the operation of the 747/piggyback or the C-5A are currently available, rates for use of a "Guppy" aircraft were used.

The estimate for mission-unique facilities reflects the estimated monthly lease rate for a DOMSAT transponder channel to provide real-time mission support data to the user center.

Both supporting function and test and operation requirements are included in the personnel estimates. Average aerospace industry rates for each of the required skill codes were used in the computation.

Launch site costs are essentially the same for Concepts I and V. Also, launch site costs are the same for the other concepts. Note the LS delta costs between I and V and the other concepts is almost completely assumed by the Level II integrator. In Concept I, the IC assumes the costs; in Concept V, the user assumes the costs.

Comparison of IC and user costs in the various concepts indicates the relative or proportionate participation and cognizance of the two centers in the integration process.

Table 6.1-1. Summary of Mission-Unique Costs (Thousands of Dollars) (Per Mission)

COST ITEM \ CONCEPT / CENTER	I				II & VII				III & VI				IV & VIII			V		
	U	IC	LS	TOTAL	U	IC	LS	TOTAL	U	IC	LS	TOTAL	U	LS	TOTAL	U	LS	TOTAL
MATERIAL	-	69	-	69	-	69	-	69	37	32	-	69	69	-	69	69	-	69
TRAVEL	30	28	2	60	32	32	3	67	45	4	5	54	43	4	47	37	2	39
AUTO COMP	16	10	1	27	16	9	2	27	25	-	2	27	25	2	27	25	1	26
DOCUMENTATION	2	3	-	5	2	3	1.5	6.5	3	1.5	1.5	6	3	2	5	3	1	4
SHIPPING/TRANSPORT	16	24	-	40	16	24	-	40	44	12	-	56	32	-	32	32	-	32
FACILITIES	40	-	-	40	40	-	-	40	40	-	-	40	40	-	40	40	-	40
PERSONNEL	373	1005	148	1526	392	916	258	1566	1019	264	258	1541	1230	258	1488	1321	148	1469
TOTAL	477	1139	151	1767	498	1053	264.5	1815.5	1213	313.5	266.5	1793	1442	266	1708	1527	152	1679

The cost variations between concepts are primarily due to the differences in manpower and travel requirements. In general, the data indicate that from a composite NASA standpoint, the more services a Spacelab user sublets the greater the total mission-unique costs will be. But the difference is only of the order of 8 percent from the high to the low estimate. Therefore, the mission-unique costs will not be a prime factor in establishing the preferred processing concept.

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6.2 SUSTAINING COSTS

A summary of the yearly sustaining costs is presented in Table 6.2-1. The data reflect the study baseline flight rate of two per year. All estimates are in 1974 dollars.

GSE and facility maintenance figures were based upon cost estimating relationships developed by Rockwell in previous space programs. The institutional base/administrative cost estimates are based upon percentages of the mission-unique costs for two flights per year. Personnel costs reflect average aerospace industry rates for the skill levels required by each sustaining organization and pro-rated as defined in Section 4.1.

The trend in the sustaining costs follows the same pattern as the mission-unique costs. The greater the direct involvement and cognizance of the user, the less the total costs. But again, the deltas between concepts are not exceedingly large ($\approx$ \$100K per year maximum) and different but equally justifiable pro-rations might reduce the variations to a negligible value. Over 86 percent of the sustaining costs are attributed to personnel requirements. There is no distinct advantage to one concept over the other from the standpoint of sustaining costs.

Table 6.2-1. Summary of Yearly Sustaining Costs (Thousands of Dollars) (Two Flights Per Year)

COST ITEM \ CONCEPT / CENTER	I				II/VII				III/VI				IV/VIII			V		
	U	IC	LS	TOTAL	U	IC	LS	TOTAL	U	IC	LS	TOTAL	U	LS	TOTAL	U	LS	TOTAL
GSE MAINTENANCE	-	21	2	23	-	18	4	22	18	4	4	26	18	4	22	21	2	23
FACILITY MAINTENANCE	-	12	1	13	-	12	2	14	12	3	2	17	12	2	14	12	1	13
INSTITUTIONAL BASE & OTHER ADMINISTRATIVE	22	38	6	66	23	35	10	68	46	10	10	66	54	10	64	57	6	63
PERSONNEL	494	140	26	660	494	140	36	670	550	14	36	600	550	36	586	550	26	576
TOTAL	516	211	35	762	517	205	52	774	626	31	52	709	634	52	686	640	35	675

6.3 NON-RECURRING COSTS

Two sets of data are presented for non-recurring costs. The first set (Table 6.3-1) presents the data for all eight processing concepts. The second set of data (Table 6.3-2) reflects the combining of GSE requirements for the processing of both the complete Spacelab and pallet-only configurations. As indicated in previous sections, the similarity in the integration and checkout activities associated with the processing of the two Spacelab configurations is negligible. Facility requirements are the same. The only significant difference in the resource requirements for processing the two configurations is the GSE required. But the delta to the GSE complement for processing of a complete Spacelab to also process a pallet-only Spacelab consists of two items: an Orbiter payload specialist station simulator is required at the Level III integration site, and equipment for handling the support systems igloo is required at the Level II integration site. As the ATL program utilizes both Spacelab configurations, all concept evaluations were based upon the data that pertain to the processing of both configurations.

User facility estimates in all concepts include provisions for an operations control center and a DOMSAT ground terminal for real-time mission support ($0.5 million). Where applicable, the remainder of the user facility estimate is for the conversion of Building 1293A at Langley to an installation and checkout building as defined in Section 5.3. The IC facility estimate is based upon preliminary planning to modify Building 4755 at MSFC to be a Spacelab processing facility. The LS facility estimate is similarly based upon preliminary plans to modify the MSOB (O&C) building at KSC for Spacelab processing.

GSE and spares estimates are based upon the complements of equipment identified in Section 5.2, with four exceptions: neither the Spacelab shipping canister nor the canister sling used for 747 piggyback shipment are included. Also, the cryogenic and hypergolic servicing units are not included in the cost estimates. All four items are considered to be general-purpose equipment that will support Shuttle users in addition to the Spacelab.

MSFC provided preliminary cost estimates for 78 of the 88 GSE items included in the cost data. Cost estimates for the other 10 items were based upon costs of comparable Apollo-Saturn equipment extrapolated to 1974 dollars.

Personnel requirements reflect only that effort required to adapt an operational Spacelab program to the specific and unique requirements of a continuing Spacelab user such as Langley.

Other than the capital investment for Spacelab flight hardware, the most significant cost items to implement a processing concept are the facilities and the GSE. If the non-recurring agency costs of Table 6.3-1 are amortized over a 10-year program, the differences between concepts (except III/VI) are not very large. Concept III/VI costs are significantly larger because of the

Table 6.3-1. Non-Recurring Costs by Concept (Millions of Dollars)

COST ITEM \ CONCEPT	I			II			III			IV		V		VI			VII			VIII	
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	LS	U	LS	U	IC	LS	U	IC	LS	U	LS
FACILITIES	0.5	3.5	0.5	0.5	3.5	0.5	2.4	3.5	0.5	2.4	0.5	2.4	0.5	2.4	2.5	0.5	0.5	2.5	0.5	2.4	0.5
GSE	-	8.9	4.9	-	5.9	8.6	5.6	2.7	8.6	5.9	8.6	8.9	4.9	5.9	2.5	7.9	-	6.2	7.9	6.2	7.9
SPARES	-	2.7	0.8	-	1.9	2.2	1.9	0.1	2.2	1.9	2.2	2.7	0.8	2.4	0.1	1.9	-	2.4	1.9	2.4	1.9
PERSONNEL	*	0.4	*	*	0.4	*	0.6	0.1	*	0.6	*	0.9	*	0.6	0.1	*	*	0.4		0.6	*
TOTAL	0.5	15.5	6.2	0.5	11.7	11.3	10.5	6.4	11.3	10.8	11.3	14.9	6.2	11.3	6.2	10.3	0.5	12.4	10.3	11.5	10.3
	22.2			23.5			28.2			22.1		21.1		27.8			23.2			21.8	

*LESS THAN $100K

Table 6.3-2. Composite Non-Recurring Costs (Millions of Dollars)

COST ITEM \ CONCEPT	I			II/VII			III/VI			IV/VIII		V	
CENTER	U	IC	LS	U	IC	LS	U	IC	LS	U	LS	U	LS
FACILITIES	0.5	3.5	0.5	0.5	3.5	0.5	2.4	3.5	0.5	2.4	0.5	2.4	0.5
GSE	-	8.9	4.9	-	6.4	8.6	6.1	2.7	8.6	6.4	8.6	8.9	4.9
SPARES	-	2.7	0.8	-	2.4	2.2	2.4	0.1	2.2	2.4	2.2	2.7	0.8
PERSONNEL	*	0.4	*	*	0.4	*	0.6	0.1	*	0.6	*	0.9	*
TOTAL	0.5	15.5	6.2	0.5	12.7	11.3	11.5	6.4	11.3	11.8	11.3	14.9	6.2
	22.2			24.5			29.2			23.1		21.1	

*LESS THAN $100K

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duplication of facilities and GSE that occur when three centers, rather than two centers, are involved in the processing of flight hardware. But the key consideration in determining the applicability or advisability of the capital investments, indicated in Table 6.3-1, is the utilization of the facilities and GSE. For example, if a user were to invest almost $12 million (as in Concept IV), a relatively high utilization rate for a long duration would be required. The same consideration must be made for capital investments at the IC and LS.

It is recognized that the basic capability to process Spacelabs will be established at MSFC (IC) and KSC (LS) during the Spacelab development phase. But the singular set of equipment at these sites will only support a limited number of Spacelab flights per year. As the Spacelab flight rate increases, and this singular set of equipment becomes saturated, additional capability must be added. Thus, the Spacelab flight rate or processing rate is the key parameter in justifying the capital investment regardless of where the equipment is located.

As both MSFC and KSC will have the basic capability to process Spacelab flight hardware, the non-recurring costs incurred by the user in the various concepts are the significant data. In Concepts I and II/VII, the user's costs are only about $0.5 million. Even these costs can be all but eliminated if only real-time voice links and non-real-time data are required (elimination of the OCC). In Concepts III/VI and IV/VIII, a capital investment by the user of about $12 million is required. An investment of this magnitude makes it imperative that the user have either a long-range/high-usage program planned or stringent proprietary/security requirements that dictate on-site Level III integration. Concept V imposes an additional $3 million investment on the user for GSE associated with the processing of the support module and systems igloo (SM/SI). Also, the user must acquire the SM/SI in Concept V. Only continuous usage of the SM/SI or the most stringent security requirements would justify the user capital investments associated with Concept V.

The currently defined ATL program is 10 years in duration with flight rates of 2 to 4 per year. Based upon the non-recurring cost data, all processing concepts, except V, could be applicable to the ATL program.

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6.4 COST-RISK RELATIONSHIPS

This section presents the results of an analysis of the cost-risk relationships associated with the elimination of certain tests from the checkout and integration plan. The tests considered were:

1. A vibration-acoustic test of the flight pallet and experiments with all experiment equipment in place.

2. A thermal-vacuum chamber test of the flight pallet and experiments with all experiment equipment in place.

3. A functional checkout of the experiments at the launch site prior to launch.

The SUIAS study procedure provided that the integration plan be based on a selection of minimum test requirements which would optimize the system for lowest possible cost. The above tests were deleted from the plan on the basis of a consensus of engineering judgment that they were not essential and that their elimination would result in lower overall costs without significant impairment of the mission objectives. The purpose of the cost-risk analysis was to provide an additional assessment of the deletion of these tests in terms of the possible cost consequences.

The nature of the analysis was to compare the cost savings derived from the deletions with the potential cost penalties which could be incurred due to consequent experiment failures in flight, and the need to recycle and refly the failed experiments.

The analysis was based on integration and checkout concept IV; however, the results are applicable generally to all concepts because only small differences in the cost comparison would result.

DESCRIPTION OF TESTS

The possible inclusion of the tests under consideration in the checkout and integration cycle is illustrated in Figure 6.4-1. Although the figure shows all three tests, the possible inclusion of each test is analyzed separately in this study. It was assumed that the vibration-acoustic and thermal-vacuum tests would be conducted at a site such as JSC, where suitable facilities for these tests are available. It was assumed that the payload specialist crew members would be utilized in all three tests to increase their proficiency in operation of the experiment equipment as well as provide on-site payload expertise.

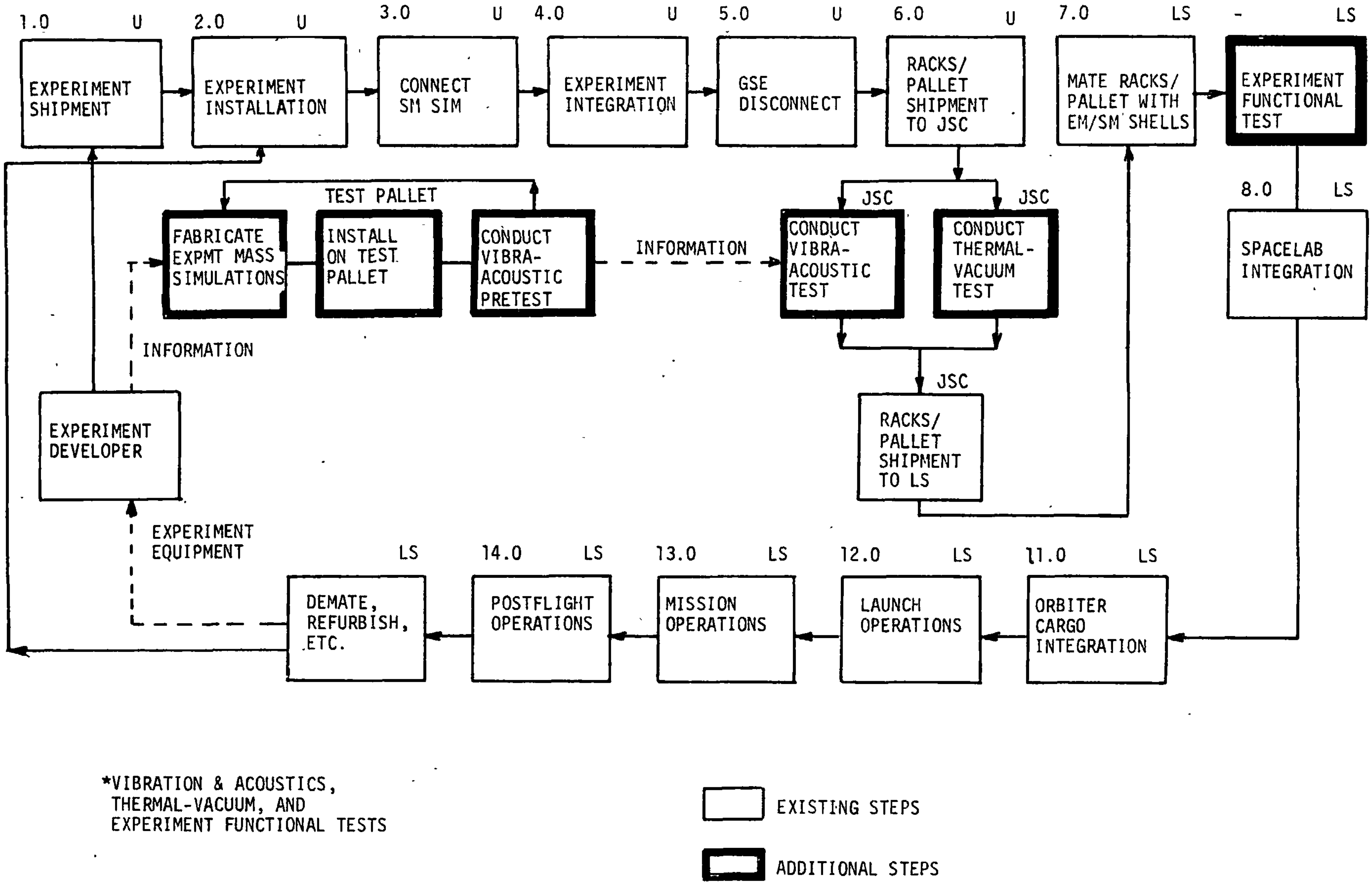


Figure 6.4-1. Addition of Tests* to Concept IV Flow

Vibration-Acoustic Test

In the case of the vibration-acoustic test, the integration flight pallet would be mounted in a support fixture which simulates the dynamic characteristics of the Orbiter cargo bay and placed in a vibra-acoustic chamber. The test would be conducted at predicted levels of vibra-acoustic intensity which would occur during the boost phase of flight. The experiment equipment would not be powered during the test; however, all fluid and gas lines would be in place, filled, and pressurized. Following the test, the pallet and equipment would be removed from the chamber and placed on a workstand where an inspection, connection of rack/end cone/pallet interfaces, and operational checkout of experiment equipment would be conducted to assess the impact of the test and recertify completion of Level III integration. The terminology "operational checkout" is used to differentiate between the functional checkout of Level III integration and the reverification of rack/pallet interfaces.

The entire vibra-acoustic test would be preceded by a pre-test run which would be conducted on dummy masses, simulating the experiment equipment and mounted on supporting structures on the pallet which are the same as those designed to support the actual flight experiment equipment. For this purpose it was assumed that an extra pallet, called the "test pallet," would be purchased and maintained at the test site. The purpose of the pre-test would be to evaluate and provide the opportunity to eliminate the possibility of damaging the experiment flight equipment during the actual test run. It is assumed that individual experiment equipment will have undergone appropriate vibration and acoustic qualification tests during the development of the experiments. The purpose of the complete pallet tests then would be to evaluate additional loads induced by the interaction of the experiment supporting structure and the pallet in the vibration-acoustic environment.

A scenario for the conduct of the vibra-acoustic test is presented in Table 6.4-1. Figures 6.4-2 and 6.4-3 present the test sequence, timing, user manpower estimates and required GSE. Manpower costs to operate the test facility are included in the lease/usage for the facility. The test pallet, support fixture, and required GSE would be purchased and maintained at the test site. The integrated flight pallet along with the experiment equipment racks would be shipped to the test site for each test. Only the post-test shipment is shown as a delta due to this test. The shipment to the vibra-acoustic facility is considered to be equivalent to the normally required shipment from the Level III integration site to the LS.

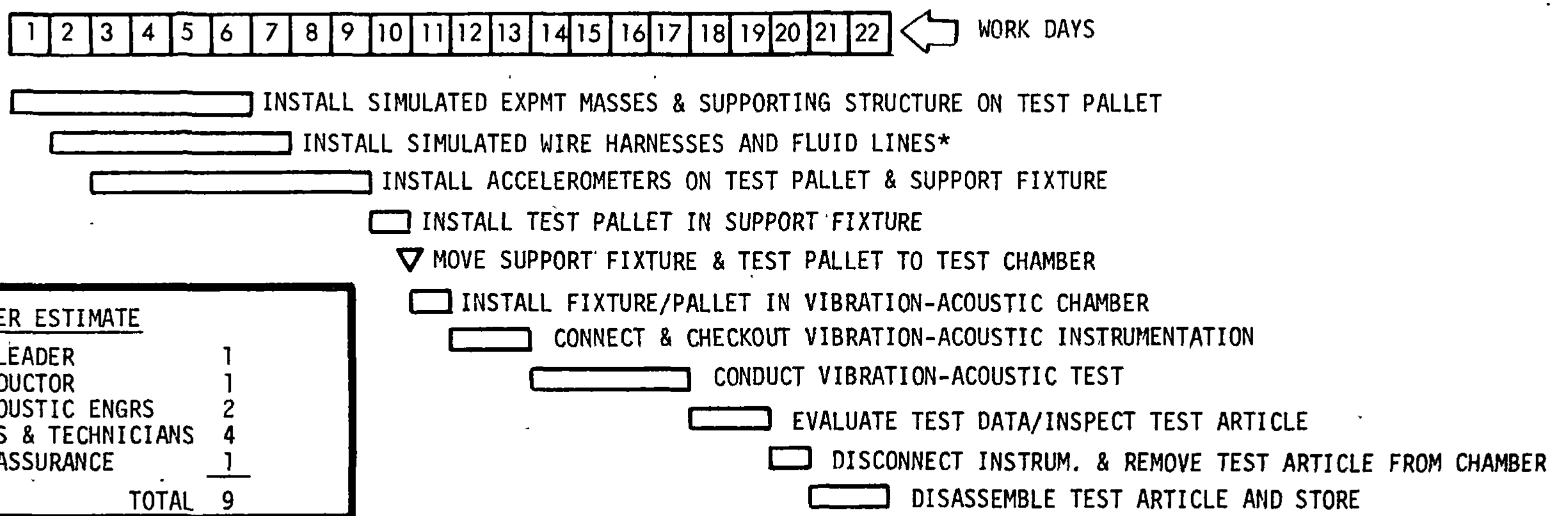
Thermal-Vacuum Test

For the thermal-vacuum test, the integrated flight pallet would be mounted on a fixture, which simulates the thermal characteristics of the Orbiter cargo bay, in a thermal-vacuum chamber. Pallet-mounted equipment would be powered during the test to the extent necessary to evaluate thermal loads. The test would simulate a flight sequence at simulated flight levels of intensity. Following the test, the pallet would be removed and placed on a workstand for inspection, connection of rack/end cone/pallet interfaces, and operational checkout of the experiment equipment to recertify completion of Level III integration.

Table 6.4-1. Vibration-Acoustic Test Scenario

PRE-TEST RUN (PALLET WITH SIMULATED EXPERIMENT MASSES)
1. Fabricate simulated experiment masses from experiment design drawings. (Mass and moment characteristics, support and interfaces precisely simulate experiments installed on the pallet.)
2. Install simulated masses and support structure on test pallet.
3. Install simulated wire harnesses and fluid lines on pallet.
4. Install accelerometers on test article and support fixture.
5. Install test pallet in support fixture.
6. Install fixture/pallet in vibra-acoustic test chamber.
7. Connect and check out vibration instrumentation.
8. Conduct acoustic test to predicted boost flight levels of intensity.
9. Evaluate test results and inspect test article.
10. Disconnect instrumentation and remove fixture/pallet from test chamber.
11. Disassemble test article and fixture and store.

TEST RUN (FLIGHT PALLET WITH INSTALLED EXPERIMENTS)
1. Install accelerometers on pallet and pallet-mounted experiment equipment.
2. Install integrated pallet on support fixture.
3. Install fixture/pallet in test chamber.
4. Connect and check out vibration instrumentation.
5. Connect and check out fluid lines and pressurize.
6. Conduct test to predicted boost flight environmental levels and profile.
7. Evaluate test results and inspect pallet, experiment equipment and support fixture.
8. Disconnect instrumentation and remove fixture/pallet from chamber.
9. Remove pallet/experiments from test fixture and install in workstand.
10. Remove vibration instrumentation.
11. Reconnect racks/pallet interface (complete Spacelab only).
12. Connect and check out support module simulator.
13. Conduct experiments operational checkout.
14. Preparations and shipment of racks/pallet to LS.



USER MANPOWER ESTIMATE

PROJECT LEADER	1
TEST CONDUCTOR	1
VIBRA-ACOUSTIC ENGRS	2
MECHANICS & TECHNICIANS	4
QUALITY ASSURANCE	1
TOTAL	9

EQUIVALENT MAN-MONTHS: 9.9

1 SHIFT + 5-DAY WORK WEEK
INCLUDES PERSONNEL TRAVEL

SUPPORT EQUIPMENT

SUPPORT FIXTURE
TEST PALLET
DUMMY MASSES & SUPPORT STRUCTURE
FLUID LINES & ELECTRICAL HARNESSES

*TEST WOULD NOT REQUIRE POWER (EXCEPT INSTRUMENTATION) OR FLUID SERVICING--HARNESSES & FLUID LINES REQUIRED FOR DYNAMIC INTERACTIONS ONLY.

Figure 6.4-2. Vibra-Acoustics Chamber Pre-Test - Test Pallet and Experiment Mass Simulation

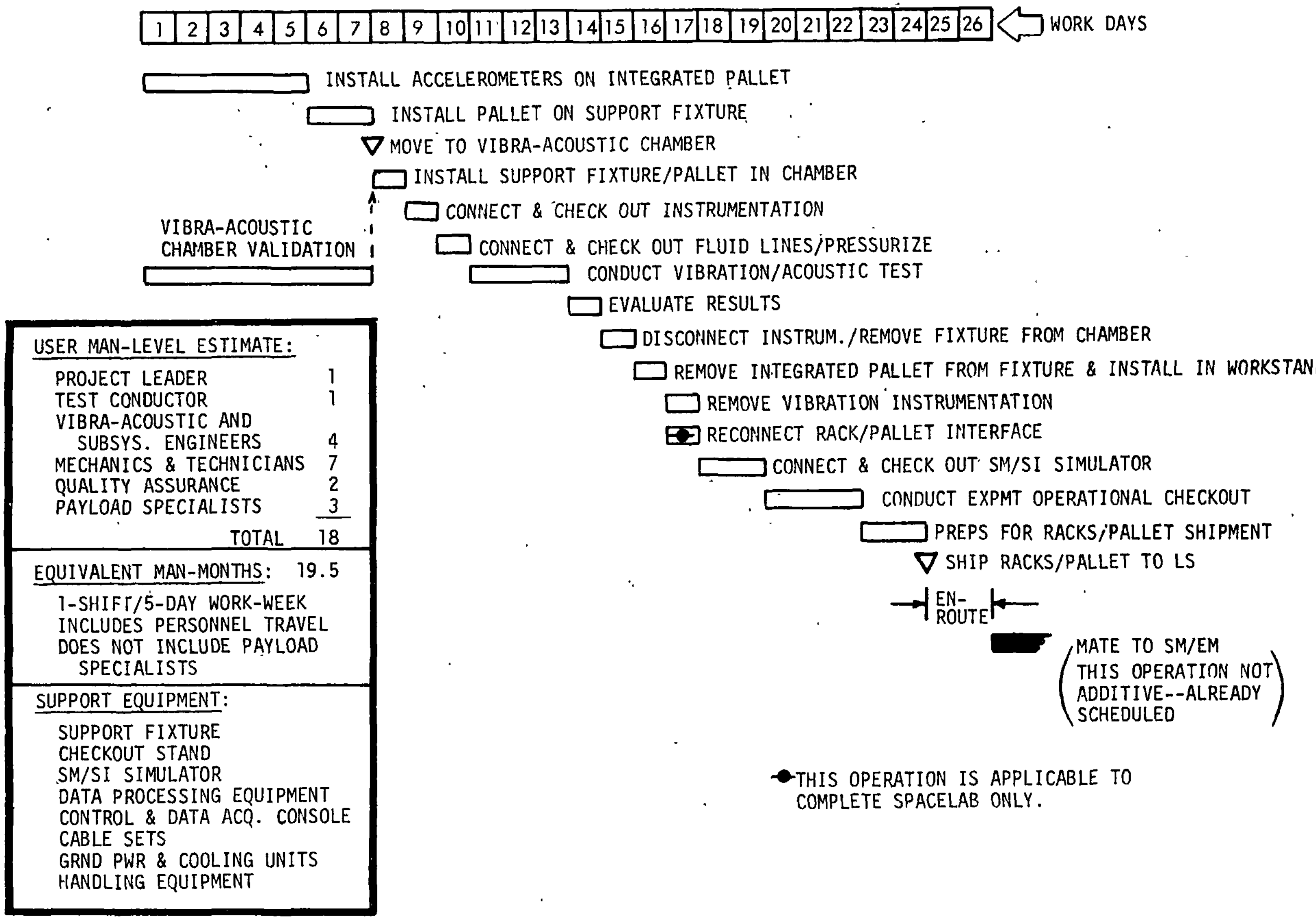


Figure 6.4-3. Vibra-Acoustics Chamber Test - Pallet With Installed Experiments

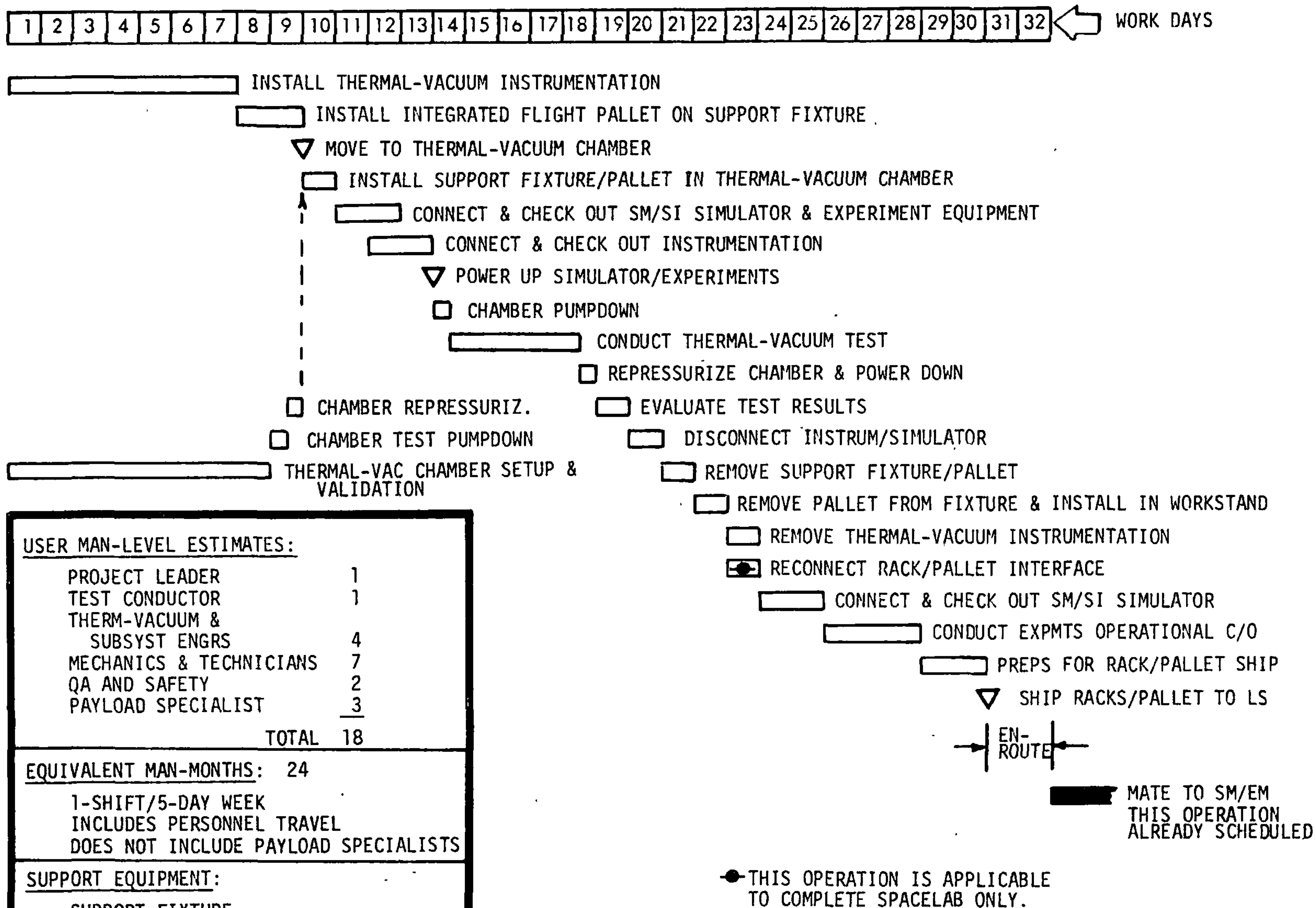
A scenario for conduct of the thermal-vacuum test is presented in Table 6.4-2. The test sequence, timing, user manpower and required GSE are shown in Figure 6.4-4. Manpower costs to operate the facility are included in the lease/usage fee for the facility. As for the vibra-acoustic test, the integrated flight pallet and experiment equipment racks would be shipped to the test site. Also, only one shipment delta is attributed to the thermal-vacuum test. The required set of GSE would be maintained at the test site.

Table 6.4-2. Thermal-Vacuum Environment Test Scenario

1. Install thermal-vacuum instrumentation on integrated flight pallet.
2. Install pallet and experiments on support fixture.
3. Install fixture/pallet in thermal-vacuum chamber.
4. Connect and check out test instrumentation, experiment equipment and SM/SI simulator (racks and simulator located outside chamber).
5. Pump down chamber.
6. Conduct thermal-vacuum test to predicted mission (orbital) environments. (Apply full power per mission profile. Perform experiment functions only for thermal effects. Control chamber environment per mission profile.)
7. Pressurize chamber
8. Evaluate test results and inspect pallet/experiment hardware.
9. Disconnect support equipment and recording equipment and remove fixture/pallet from chamber.
10. Remove pallet from support fixture and install workstand.
11. Remove instrumentation sensors.
12. Reconnect racks/pallet interface (complete Spacelab only).
13. Connect and check out SM/SI simulator.
14. Conduct experiments operational checkout.
15. Preparations and shipment of racks/pallet to LS.

Experiment Functional Checkout at the Launch Site

The LS functional checkout referenced in this section duplicates about 50 percent of the individual and integrated experiment equipment tests conducted during Level III integration. (This checkout is comparable to the testing of Apollo equipment at the launch site prior to integration with the Saturn boosters.) Experiment equipment must be activated and functionally verified. This level of testing is significantly more complex than the tests identified at the LS in the integrated flows that were developed in Volume II. The integrated flows reflect an interface verification checkout that includes limited setup/calibration/operation activities with those experiment equipments



<u>USER MAN-LEVEL ESTIMATES:</u>

PROJECT LEADER	1
TEST CONDUCTOR	1
THERM-VACUUM & SUBSYST ENGRS	4
MECHANICS & TECHNICIANS	7
QA AND SAFETY	2
PAYLOAD SPECIALIST	3
TOTAL	18

<u>EQUIVALENT MAN-MONTHS</u>: 24

1-SHIFT/5-DAY WEEK
INCLUDES PERSONNEL TRAVEL
DOES NOT INCLUDE PAYLOAD SPECIALISTS

<u>SUPPORT EQUIPMENT</u>:

SUPPORT FIXTURE
SM/SI SIMULATOR
DATA PROCESSING EQUIPMENT
MEMORY LOAD & VERIFY UNIT
GSE/FACILITY CABLE KIT
(EM RACKS & EQUIPMENT)

Figure 6.4-4. Thermal-Vacuum Test - Pallet With Installed Experiments

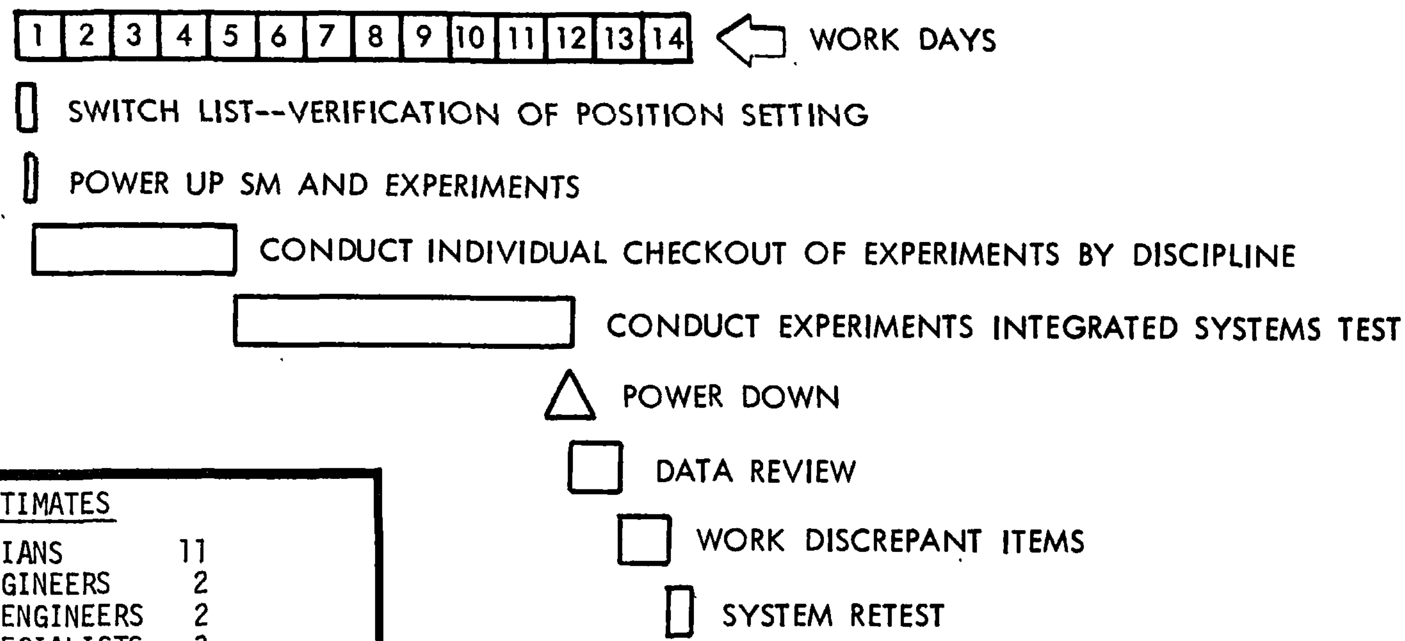
required to be activated for interface verification or calibration with Spacelab support systems. The LS tests in the integrated flows are comparable to the "operational checkouts" defined in the post-vibra-acoustic and thermal-vacuum tests described above.

Two approaches were considered for the conduct of the functional checkout at the launch site. The sequence of activities and timing for the first approach are illustrated in Figure 6.4-5. In this case, the tests are inserted as a part of the Spacelab integration activities (Block 8.0) which were derived in Volume II, and are illustrated in this section in Figure 6.4-6. In the second approach, the functional checkout would be conducted at a separate Level III checkout station equipped for this purpose. The sequence of activities, timing, and GSE for the second approach are presented in Figure 6.4-7.

In the first approach the GSE and other equipment required for the test are also required for Spacelab integration, so that the only significant delta to the resource requirements for Spacelab processing would be the additional time of 14 days and the additional manpower required. This would be a satisfactory approach for a single test on an isolated payload. On a continuing basis, however, the programmatic implication of the addition of 14 days to the processing schedule of all Spacelabs must be considered. This approach involves the use of flight Spacelab equipment and results in an increased involvement time of 28 percent for the SM and 35 percent for the SI for each mission. In order to support the nominal yearly traffic model used in this study (24 Spacelab flights per year), an additional SM and SI would be required. Although the test sequence presented in Figure 6.4-6 was based upon a 1-shift/5-day work week, the same net effect of inclusion of an experiment functional checkout during Spacelab integration would result if 2-shift operations were scheduled. The required complement of SM's and SI's would increase by one. Three, rather than two, SM's would be required and two, rather than one, SI would be required to support the Spacelab traffic model. Based on a 2-shift/5-day work week, the SM's required would be increased from 2 to 3, and the SI's required would be increased from 1 to 2.

In the second approach a Level III integration stand would be used for the test. A Level III integration stand is included in the preliminary planning for Spacelab processing at KSC, but this stand is designated for contingencies, revisions, minor modifications, additions, and substitutions for payloads after arrival at KSC. It is anticipated that utilization of this Level III check station will be very high. Even if an idealized 2-shift operation rather than the one-shift operation, reflected in Figure 6.4-7, is assumed for the functional testing of all Spacelab payloads, a Level III test stand would be almost continuously utilized to support the traffice model (48 out of 52 weeks). Therefore, an additional checkout station would be required to support the second approach for a Level III integrated functional checkout at the launch site.

Because the capital investment for an additional flight SM and SI is significantly greater than for an additional Level III checkout station, the second approach is considered more desirable and is adopted for the purpose of the present analysis. The delta GSE is identified in Figure 6.4-7. It is believed that revision to the MSOB at KSC to accommodate the additional checkout station would be minor and thus no facility modification costs have been included in the analysis.



MAN-LEVEL ESTIMATES	
LS TECHNICIANS	11
LS TEST ENGINEERS	2
USER TEST ENGINEERS	2
PAYLOAD SPECIALISTS	3
TOTAL	18
EQUIVALENT MAN-MONTHS	10.5

1-SHIFT/5-DAY WORK WEEK
NO DELTA TRAVEL TIME
DOES NOT INCLUDE
PAYLOAD SPECIALISTS

Figure 6.4-5. Experiment Functional Checkout at Launch Site During Level II Integration

```
***1***2***3***4***5***6***6***8***9**10**11**12  WORKING DAYS

***  CONNECT GSE(SERV UNITS,ORBITER I/F SIM & OTHER SUPPORT GSE)
   **  SERVICE & VERIFY COOLANT FLOW THROUGH GSE, FLD LINES, & COLDPLATES
     *  PERFORM BUS ISOLATION TESTS
      *  CONDUCT PRE-PWR SW LIST CK TO VERIFY SW & CONTROL SETTINGS
       *  PWR UP ELECT & FLUID SYSTEMS
       *  CONDUCT PWR DISTRIBUTION  CHECKS
        *  VERIFY CAUTION & WARNING SYS OPERATION -SENSORS & DISPLAYS
        *  POWER UP SUPPORT MODULE IMS
        *  CONDUCT COMPUTER SELF CHECKS
         **  VERIFY SM IMS COMMAND/CONTROL
           *  CHECKOUT EM-IMS PERIPH EQUIP - PRINTERS, RECORDERS, ETC
           *  C/O AUX EQUIP- CCTV, I/C, LIGHTING, ETC.
           *  CHECK SIG DISTR VIA SW-ORBITER UMBILICAL
            *  VERIFY GND DATA BASE COMPATIBILITY VIA THE GDB UMB
            ****  CONDUCT FUNCT C/O OF SUPPORT SYS/EXPMT EQUIP I/F'S
                *  PWR DOWN SL & SUPPORT EQUIP
                *****  DATA REVIEW
          Insert - CONDUCT OF FUNCTIONAL C/O OF EXPERIMENTS
                    *****  DISCONNECT GSE
                    *****  LOAD NON-HAZARDOUS SUPPLIES & CREW EQUIP
                       **  CLOSEOUT SL PANELS, HATCHES & ACCESS PANELS
                        ***  RETOUCH SL EXTERIOR WITH THERMAL PAINT
                           ***  CONDUCT EMISSIVITY TESTS
                             **  PREPS FOR SL PRESS DECAY LK CHECK
                               ****  CONDUCT SL LK CK (24 HR PRESS DECAY-16 HRS ON 2&3RD SHIFT
                                  *  DEPRESSURIZE SL & REMOVE GSE
                                  ****  CONDUCT WEIGHT & BALANCE TEST
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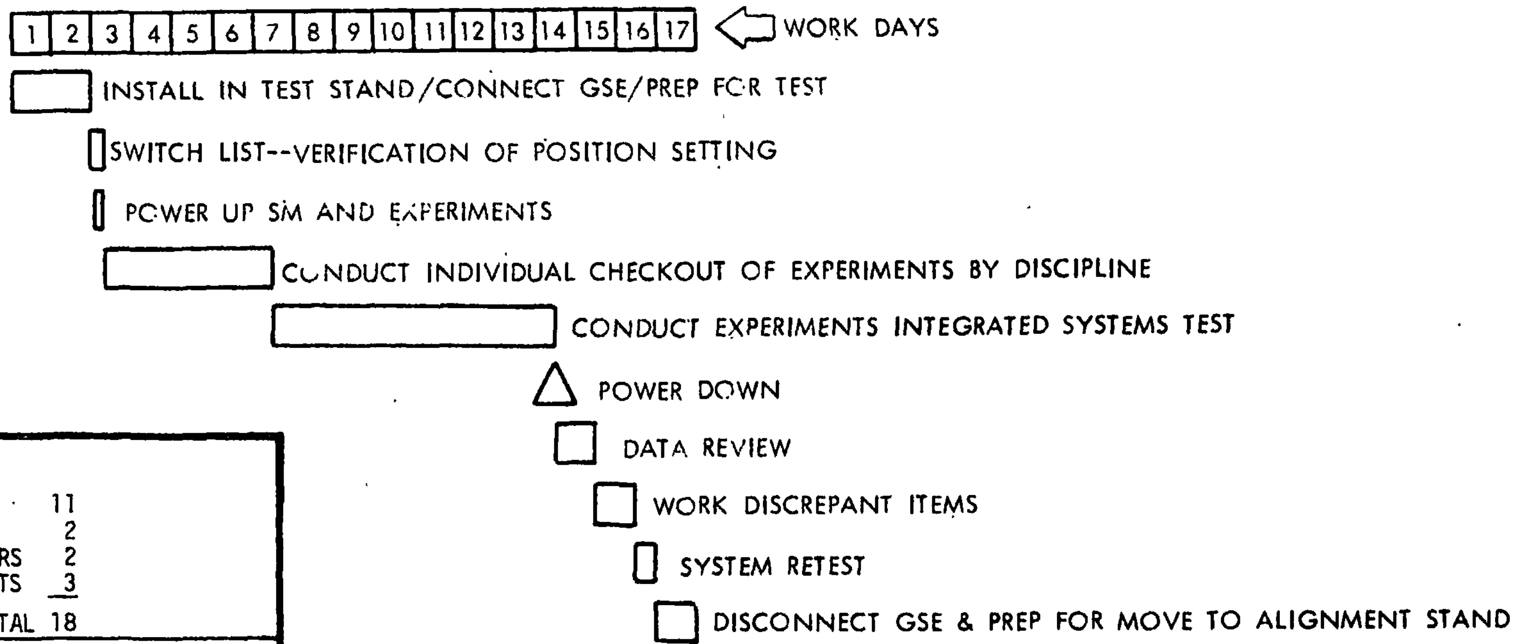
Figure 6.4-6. Spacelab Integration (Block 8.0) Test Sequence



MAN-LEVEL ESTIMATES

LS TECHNICIANS	11
LS TEST ENGINEERS	2
USER TEST ENGINEERS	2
PAYLOAD SPECIALISTS	3
TOTAL	18

EQUIVALENT MAN-MONTHS 12.3

1-SHIFT/5-DAY WORK WEEK
NO DELTA TRAVEL
DOES NOT INCLUDE PAYLOAD SPECIALISTS

SUPPORT EQUIPMENT

CHECKOUT STAND
SM/SI SIMULATOR
DATA PROCESSING EQUIPMENT
GROUND POWER SUPPLY
CONTROL & DATA ACQUIS. CONSOLE
EXPERIMENT TEST CABLE SET
GSE/FACILITY CABLE SET
GROUND AIR-COOLING UNIT

Figure 6.4-7. Experiment Functional Checkout at Launch Site Prior to Level II Integration

RESULTS OF ANALYSIS

The results of the analysis are shown in Figures 6.4-8 and 6.4-9. These figures compare the cost of conducting each test with the alternative cost of reflying a portion of the payload on a subsequent flight as a result of a failure which the test would have detected if it had been conducted. The comparison is shown parametrically as a function of the probability of failure and for various portions of the payload which might be affected. The first figure is based solely on payload processing reflight costs. The second figure shows the results if Shuttle flight costs are considered in the reflight costs.

The detailed data on the cost of conducting the tests are presented in a subsequent paragraph entitled "Test Cost Estimates." The total costs for the conducting of each vibra-acoustic, thermal-vacuum, or delta functional checkout test are $607K, $337K and $129K, respectively. A per-flight cost of $1.7 million (excluding Shuttle costs) was based on the mission-unique costs for processing Spacelab payloads through the checkout and integration sequence of Concept IV (reference Section 6.1). In Figure 6.4-9, Shuttle flight costs were assumed to be $12 million per flight, computed in 1974 dollars. The development of the mathematical model for calculation of the cost-risk comparisons is presented in a subsequent section.

Payload Processing Cost-Risk Evaluation

If only payload re-processing costs are considered in the cost-risk evaluations (Figure 6.4-8), the data indicate that conducting a vibra-acoustic test is considerably more costly than reflying portions of a payload because of failures that would have been detected if the test were performed. The lines that indicate the costs for 10, 20, or 30 percent of equipment reflight reflect that portion of the payload affected by a failure and thus requires reflight. For example, if there were 10 equal experiments and a failure in flight affected 3, the 30-percent cost-of-reflight-line would be applicable. The data of Figure 6.4-8 indicate that it would be less costly to refly all three experiments than to conduct pre-flight vibra-acoustic tests.

In the case of the thermal-vacuum test, the data in Figure 6.4-8 generally indicate a lower cost for reflight than for conduct of the test. For example, the probability of a failure would have to exceed 65 percent due to the thermal-vacuum environment, and such failures would have to result in a 30-percent loss of the payload capability before it would be more economical to conduct the test.

In the case of the experiment functional test, there would have to be a 25-percent probability of failure due to handling and transportation after Level III integration that would affect nearly 30 percent of all experiments before the test would be warranted on a cost basis. It is therefore judged that the data in Figure 6.4-8 support the conclusion to delete each of the three tests.

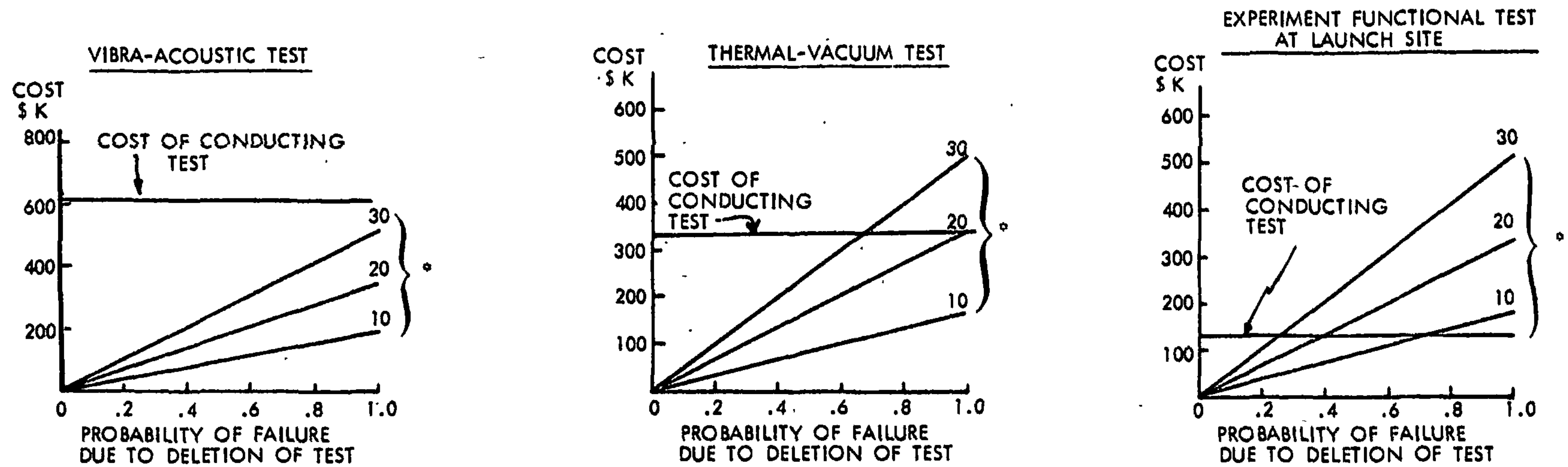
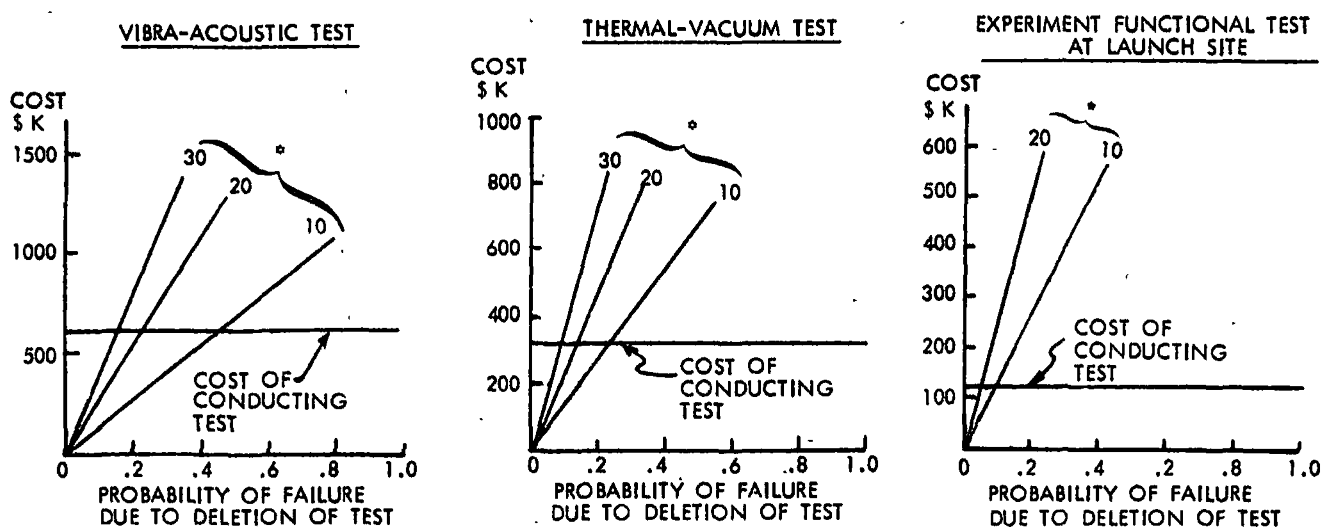


Figure 6.4-8. Cost-Risk Relationships for Deletion of Tests, Excluding Shuttle Flight Costs

*Cost of reflying, and percent of equipment reflown.



*Cost of reflying, and percent of equipment reflown.

Figure 6.4-9. Cost-Risk Relationships for Deletion of Tests, Including Shuttle Flight Costs

Spacelab/Shuttle Reflight Cost-Risk Evaluation

The same overall conclusion was reached in the cost-risk evaluations even when Shuttle flight costs were included in the reflight cost compilations. That is, it is more cost-effective to risk the possible failure of an experiment item in flight and refly the experiment on a subsequent flight than to incur the costs of any of the three tests in question. However, consideration of Shuttle flight costs significantly reduces the margin in the probabilities involved. For example, Figure 6.4-9 indicates that if there were a 15-percent probability of failure due to deletion of the vibra-acoustic and thermal-vacuum tests, the failures would have to affect over 30 and 20 percent of the experiments, respectively, before it would be more economical to conduct the ground tests. The comparable data in Figure 6.4-8 indicate that a probability of failure of 1 would have to exist before conduction of these two ground tests could be economically considered.

In the case of the experiment functional test, the decision is less clear and depends upon individual judgment of the probabilities involved. Figure 6.4-9 indicates, for example, that a probability of failure affecting 10 percent of the payload would have to exceed about 12 percent before the test would be warranted on this basis along. These data did not alter the decision to delete the test. Based upon the handling and transportation techniques proposed for Spacelab payloads, which include standardization and monitoring during shipping, it is believed that even lower probabilities of failure could be assumed.

Additional Considerations

These cost-risk evaluations are considered to be relatively conservative. The basic assumption in the evaluations was that a failure during flight would have been avoided if the tests would have been performed. But two other possibilities also exist if the tests are conducted: (1) the flight hardware may pass the pre-flight test and still subsequently fail during the flight; or (2) the pre-flight test may be more severe than the flight environment, and the flight hardware might fail during the ground test but would not have failed during the actual flight. Each of these possibilities is discussed below.

In-Flight Failure With Pre-Flight Testing

Each item of flight hardware will have a certain probability, p_i, of failing the i^{th} pre-flight test. If the pre-flight test is designed to simulate normal flight environments and operations, then it can be assumed that p_i will equal P_i where P_i is the probability of failure during flight because the i^{th} test was deleted. In essence, the i^{th} test has been delayed to the actual flight. But the equipment has been designed and manufactured to achieve a relatively low p_i. Therefore, the probability of passing a pre-flight test, $(1-p_i)$, would be relatively large.

Assuming $p_i = P_i$ and since the pre-flight test does not actually improve the quality of the hardware, the probability that the equipment will pass the pre-flight test and subsequently fail in actual flight would be equal to or greater than $p_i(1-p_i)$. Unless p_i is very small or very large, this probability of failure during flight even with the pre-flight tests is not negligible. (See Figure 6.4-10.) It is assumed that each set of experiment equipment is

subjected to detailed performance, functional, and environmental acceptance testing. The merit of repeating this type of testing at Level III integration, or even repetition of Level III testing during Level II integration, is questionable.

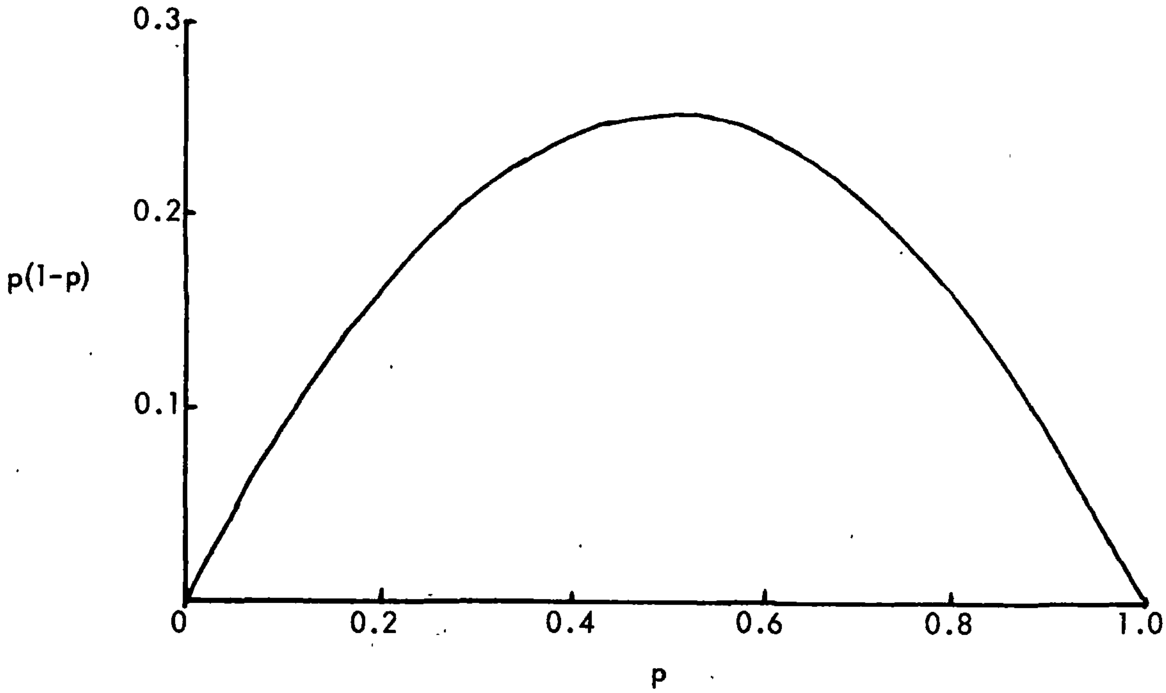


Figure 6.4-10. Probability of Passing A Pre-Flight Test but Failing During Flight (As a function of the probability of failure, p)

Pre-Flight Test Induced Failure

One of the basic problems in conducting the three tests in question is to realistically simulate the flight "environment." The thermal-vacuum and vibra-acoustic profiles that the equipment would be subjected to could be more severe than encountered during actual flight. Testing of equipment in a 1-g environment that was designed for operation in a zero-g environment can result in either over-stressing the equipment or operation in abnormal modes. Thus, p_i could actually be greater than P_i and the potential costs of modifying and re-testing of equipment that fails a ground test that is more severe than the flight must be considered. Inclusion of the costs of failures induced by ground tests would add another probability dimension to the cost-risk data of Figures 6.4-8 and 6.4-9. The cost of conducting a test would become a family of curves (instead of one value) to reflect various probabilities of failure due to the ground test environment. The effect on the cost-risk relationship is illustrated in Figure 6.4-11, and obviously supports the recommendation for deletion of the subject ground tests.

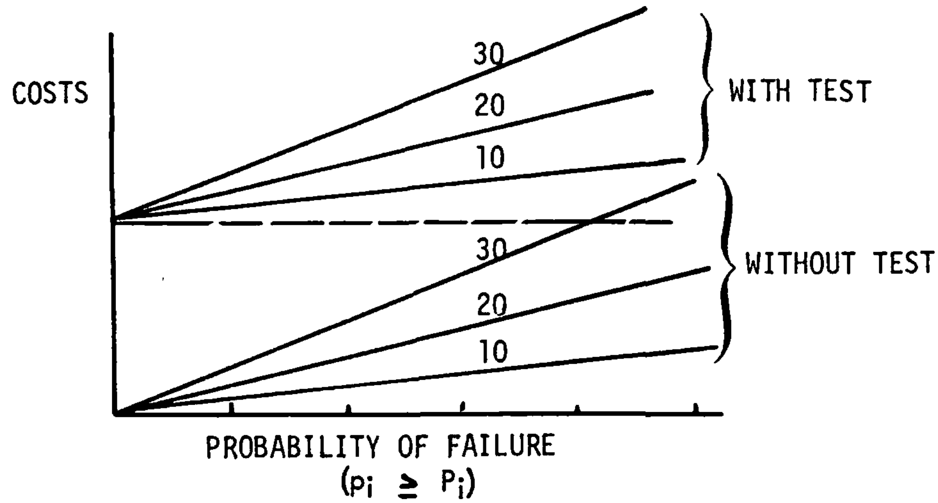


Figure 6.4-11. Impact on Cost-Risk Relationship With Test-Induced Failures

Operational Considerations

One final consideration in the deletion of the subject ground tests was the fact that most of the experiments will be flown more than once to fully exploit their capabilities. Thus, the subject tasks would be repetitious for many items of flight hardware. Previous flight experience is considered to be a better measure of performance/capability of hardware than additional ground testing.

TEST COST ESTIMATE

Compilations of the cost estimates for the three tests considered in the cost-risk analysis are presented in Table 6.4-3. The table presents order-of-magnitude cost values to a degree of accuracy considered necessary for the comparison with flight cost estimates presented in the cost-risk relationships The estimates of manpower, GSE and other cost elements are based on the descriptions of these tests contained in the earlier parts of this section.

An initial consideration in development of the estimates was the cost and location of suitable facilities for the conduct of the vibra-acoustic and thermal-vacuum tests. An investigation was made of available facilities, and a compilation of applicable existing facilities and their capabilities is presented in Tables 6.4-4 and 6.4-5. Some of these facilities are described in "*An Inventory of Aeronautical Ground Research Facilities*," NASA CR 1876.

The cost estimates for the use and operation of suitable vibration-acoustic facilities are based upon the charges that would be made for the use of such facilities on a contract basis. Although NASA facilities might be used in a NASA program on an accommodation basis at reduced cost, it was felt that a contractual situation would more accurately reflect the total cost. In the case of the thermal-vacuum test, data were based on discussions with Rockwell test facility personnel, data on the use of the AEDC facility, and recent experience in a Rockwell contractual use of the MDAC Huntington

Table 6.4-3. Cost Compilations For Tests

VIBRATION-ACOUSTIC TEST		
	PRE-TEST RUN	TEST RUN
VIBRA-ACOUSTIC FACILITY USE AND OPERATION	$ 25,000	$ 25,000
VIBRA-ACOUSTIC TEST LABOR		
9.9 MM @ $3000	35,000	
19.5 MM @ $3000		52,000
INSTRUMENTATION & RECORDING, 60 @ $325 (EACH TEST)	20,000	
DUMMY MASSES & DUPLICATE INTERFACE STRUCTURES		
23 MM x $3000 x 2 (MATERIAL = LABOR)	138,000	--
PERSONNEL TRAVEL AND SUBSISTENCE		
TRAVEL (LANGLEY-JSC)		
9(PEOPLE) x $244 (ROUND TRIP AIRFARE)	12,000	
TRAVEL (LANGLEY-JSC)		
15(PEOPLE) x $244 (ROUND TRIP AIRFARE)		23,000
SUBSISTENCE		
15(PEOPLE) x 36 (CALENDAR DAYS) x $35 (PER-DIEM)		
SHIPPING (SIMULATED EQUIPMENT & FLIGHT HARDWARE)	15,000	15,000
TEST PALLET (ASSUME $2,500,000) PRO-RATED OVER 20 TESTS	125,000	--
SUBTOTAL	$ 370,000	$ 135,000
GROUND SUPPORT EQUIPMENT $2,046,000		
SM/SI SIMULATOR		
SUPPORT FIXTURE (IN CHAMBER)		
CHECKOUT STAND		
DATA PROCESSING EQUIPMENT		
CONTROL & DATA ACQUISITION CONSOLE		
CABLE SETS		
GROUND POWER & COOLING UNITS		
HANDLING EQUIPMENT		
AMORTIZED OVER 20 TESTS	$102,000	
TOTAL	$607,000	

THERMAL VACUUM CHAMBER TEST	
THERMAL-VACUUM FACILITY USE AND OPERATION	$100,000
THERMAL VACUUM TEST LABOR, 24 MM @ $3000	72,000
INSTRUMENTATION CABLES: 200 THERMOCOUPLES @ $90	
(RECORDING IN FACILITY COST)	18,000
SHIPPING FLIGHT HARDWARE TO LS FROM TEST SITE	15,000
PERSONNEL TRAVEL AND SUBSISTENCE	27,000
TRAVEL (LANGLEY-JSC)	
15 (PEOPLE) x $244 (ROUND TRIP AIRFARE)	
SUBSISTENCE	
15 (PEOPLE) x 44 (CALENDAR DAYS) x $35 (PER-DIEM)	
GROUND SUPPORT EQUIPMENT $2,119,000	
SM/SI EQUIPMENT SIMULATOR	
SUPPORT FIXTURES (VACUUM CHAMBER)	
CHECKOUT STAND	
DATA PROCESSING EQUIPMENT	
CONTROL & DATA ACQUISITION CONSOLE	
CABLE SETS	
GROUND POWER & COOLING UNITS	
HANDLING EQUIPMENT	
VERTICAL ACCESS SCAFFOLDING	
AMORTIZED OVER 20 TESTS	105,000
TOTAL	$337,000

Table 6.4-3. Cost Compilations For Tests (Cont)

FUNCTIONAL CHECKOUT OF EXPERIMENTS AT LAUNCH SITE	
TEST LABOR, 12.3 MAN-MONTHS AT $3000	$ 37,000
PERSONNEL SUBSISTENCE	
2 (PEOPLE) x 25 (CALENDAR DAYS) x $35 (PER-DIEM)	2,000
GROUND SUPPORT EQUIPMENT $1,786,550	
SM/SI SIMULATOR	
CHECKOUT STAND	
DATA PROCESSING EQUIPMENT	
CONTROL & DATA ACQUISITION CONSOLE	
CABLE SETS	
GROUND POWER & COOLING UNITS	
AMORTIZED OVER 20 TESTS	90,000
TOTAL	$129,000

Table 6.4-4. Vibration-Acoustic Chamber Test Facilities

FACILITY	TYPE	TEST ARTICLE CAPACITY (FT)	MAXIMUM SOUND PRESSURE (dB)	FREQUENCY RANGE (Hz)
AFFDL/WPAFB	REVERBERATION AND PROGRESSIVE WAVE CHMBR	70 x 56 x 42 H	162/174	50 TO 10K
JSC	REVERBERATION AND PROGRESSIVE WAVE CHMBR	60 x 70 x 105 H	153/169	20 TO 20K
LTV, DALLAS	REVERBERATION CHAMBER	15 x 15 OPENING	148	50 TO 10K
LOCKHEED M&SG	REVERBERATION CHAMBER	40 x 50 x 86 H	156	40 TO 10K
WYLE LABS, HUNTSVILLE	REVERBERATION CHAMBER	40 x 50 x 60 H	155	25 TO 10K
ATL REQUIREMENT		15D x 55 MAXIMUM	145	31.5 TO 8K

Table 6.4-5. Thermal-Vacuum Chamber Test Facilities

FACILITY	DIMENSIONS (FT)	VACUUM (TORR)	SOLAR SIMULATOR	COLD TEMPERATURE
AEDC	34 D x 65.5 H	5×10^{-7}	YES	LN_2 WALLS
JSC	40 D x 60 H	1×10^{-6}	YES	LN_2 WALLS
GODDARD	77.5 D x 40 H	1×10^{-9}	YES	-163 C
ATL REQUIREMENT	30 D x 60 H	1×10^{-6}	YES	DEEP SPACE

Beach facility. In the case of the vibra-acoustic facilities, the figure is based on experience and discussions with Rockwell test facility personnel, and upon discussions and a quotation obtained from Wyle Labs, Huntsville, Alabama.

Shipping and personnel travel cost estimates for the vibra-acoustic and thermal-vacuum tests were based on the assumption that the tests would be conducted at a site remote from the user facility, such as JSC.

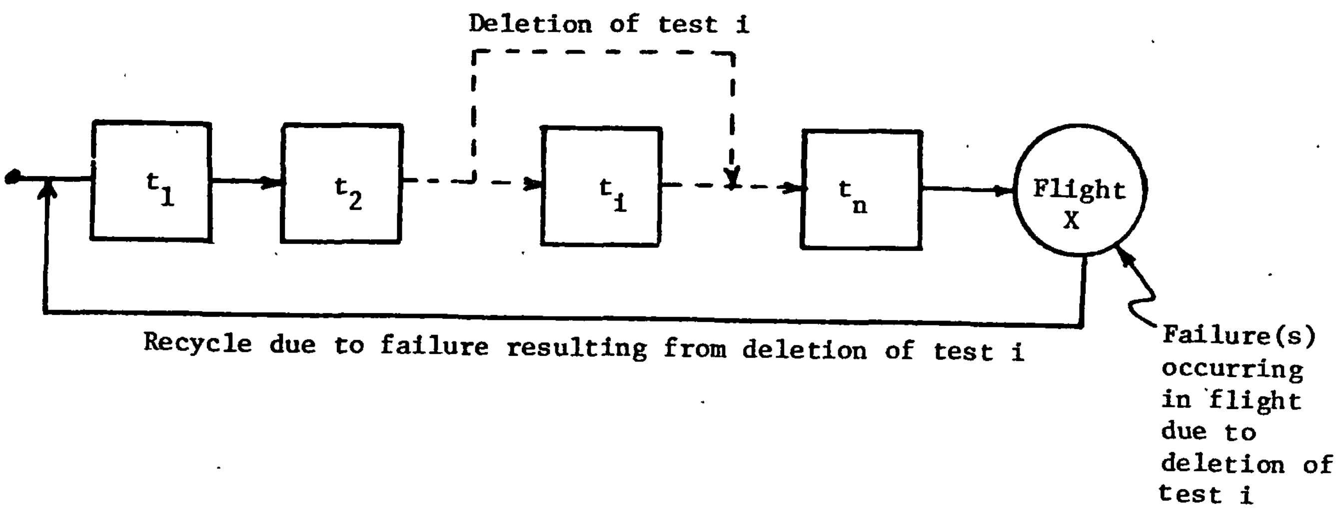
All capital investment costs such as acquisition of a test pallet, support fixtures and GSE costs were amortized over 20 tests. This would reflect 10 years' use at two flights per year.

In the case of the functional checkout of experiments at the launch site, GSE costs are included because of the requirement (discussed earlier) for an additional test station. It was assumed, however, that other facilities would be made available on a no-cost basis.

ANALYTICAL MODEL OF THE COST-RISK RELATIONSHIP

This section presents the development of the mathematical model for calculation of the cost-risk relationships presented in Figures 6.4-8 and 6.4-9. The relationship is illustrated graphically in Figure 6.4-12, and is developed as follows.

Given the following integration sequence



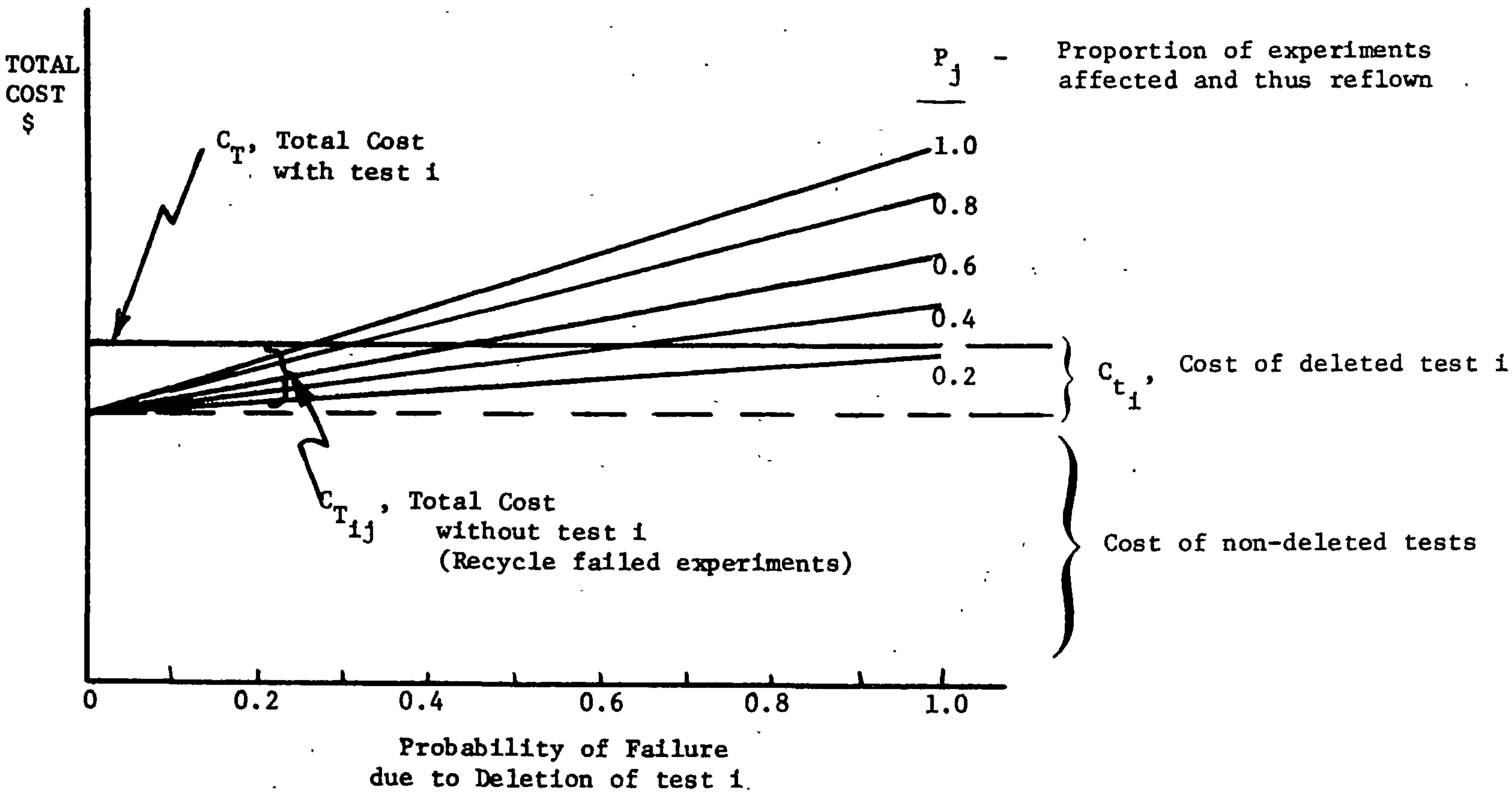


Figure 6.4-12. Theoretical Cost-Risk Comparison

Let:

t_i = Test i, a test or step in the checkout and integration process

C_{t_i} = Cost of test i

n = Number of tests

P_i = Probability of failure due to deletion of test i

P_j = Portion of experiments affected by failure

$C_{R_{ij}}$ = Cost of recycle of portion of experiments, j, which failed due to the deletion of test i

C_T is defined as the total cost of all tests for the checkout and integration of a set of experiments for flight and is

$$C_T = \sum_{i=1}^{n} C_{t_i}$$

P_i and $C_{R_{ij}}$ can be combined to give the "expected value" of the cost of recycle of the portion of experiments failed due to the deletion of test i.

Expected recycle costs = $P_i \ C_{R_{ij}}$

The expected value of the cost is the mean value of the cost if the same situation were to occur a large number of times.

The expected value of cost for the test and checkout of a set of experiments with deletion of test i and including recycle costs for the portion of experiments failed is then defined as

$$C'_{T_{ij}} = C_T - C_{t_i} + P_i \ C_{R_{ij}}$$

For convenience, the term $C'_{T_{ij}}$ will be called "total cost without test i" while C_T will be called "total cost with test i".

In the normal operation of the program, a failed experiment may be expected to be modified and reinstalled with a new set of experiments in the Spacelab in preparation for another flight. The failed experiment will then pass through all the tests and steps of the integration cycle with the new set of experiments

so that it must bear its proportionate share of the total cost of each test or step in the cycle. The total cost with the deletion of test i is $C_T - C_{t_i}$. If it is assumed that the portion of the total cost of each step or test in the integration cycle which is applicable to recycling of failed experiments is the same as P_j, the portion of the experiments which failed in flight, the cost of recycle, $C_{R_{ij}}$, can be replaced by $P_j(C_T - C_{t_i})$. Then,

$$C'_{T_{ij}} = C_T - C_{t_i} + P_i P_j \left(C_T - C_{t_i}\right)$$

and,

$$C'_{T_{ij}} = \left(C_T - C_{t_i}\right)\left(1 + P_i P_j\right)$$

In the comparison of C_T, total costs with test i, and $C'_{T_{ij}}$, total costs without test i, the terms P_i, probability of failure, and P_j, proportion of experiments affected, can be handled parametrically. The sensitivity of the cost differences to any combinations of these values may then be determined.

An illustration of the resulting comparison is given in Figure 6.4-12. To interpret the figure, consider the case where $P_j = 1$ (all experiments would be affected by a failure due to the deletion of i). In this case it is more economical to refly the experiments which failed than to conduct the deleted test i for probabilities of failure below 0.25, which is the crossover point. In other words, the probability of failure due to deletion of the test must be greater than 0.25 before it is more economical to conduct the test. As the portion P_j of experiments affected by a failure becomes less, the crossover point moves to the right. Thus, if only a small portion of the equipment is vulnerable to a failure which might have been forestalled by conducting the test, the desirability of conducting the test becomes less.

The above equations do not explicitly consider the cost of flying the Shuttle itself. Shuttle flight costs may be considered as a part of the costs to fly or refly experiments. Shuttle flight costs can be readily accommodated in the above equations, however, by simply considering the Shuttle flight to be another step or test in the cycle; i.e., in the series of tests,

$$t_1, t_2 \ldots . t_i \ldots \ldots t_n$$

The last term t_n becomes the flight, and C_{t_n} the cost of the flight.